DOCUMENT RESUME

ED 059 105 24 SE 013 404

AUTHOR	Pearce, Ella Elizabeth
TITLE	Curriculum Design for Junior Life Sciences Based Upon the Theories of Piaget and Skiller. Final Report.
INSTITUTION	Houston Univ., Tex.
SPONS AGENCY	National Center for Educational Research and Development (DHEW/OE), Washington, D.C.
BUREAU NO	BR-0-G-058
PUB DATE	Oct 71
CONTRACT	OEC-6-71-0475(509)
NOTE	156p.
EDRS PRICE	MF-$0.65 HC-$6.58
DESCRIPTORS	Biology; *Curriculum; Doctoral Theses; *Educational Psychology; Grade 7; *Intellectual Development; *Reinforcement; Secondary School Science
IDENTIFIERS	Piaget; Skinner

ABSTRACT

Four seventh grade life science classes, given curriculum materials based upon Piagetian theories of intellectual development and Skinner's theories of secondary reinforcement, were compared with four control classes from the same school districts. Nine students from each class, who(at the pretest) were at the concrete operations stage of intellectual development, were studied. Both experimental and control groups made significant gains from pre- to posttest on science achievement (Metropolitan Science Test, Advanced Level), but did not differ significantly from each other. The experimental group, however, attained higher levels of intellectual development; the experimental materials facilitated movement from the concrete to formal operations level. Details of the individually-administered Piagetian tasks, the teacher's manual for the experimental materials, one sample of the units supplied to students, and an example of the rating protocol used by the jury validating the materials are appended. (AL)

ED059105

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
OFFICE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

PA 24
BR 0-G-058
OE-NCERD
SE

Final Report

Project No. 0G058
Contract No. OEC-6-71-0475 (509)

Ella Elizabeth Pearce
University of Houston
Cullen Boulevard
Houston, Texas 77004

CURRICULUM DESIGN FOR JUNIOR LIFE SCIENCES BASED UPON THE THEORIES OF PIAGET AND SKINNER

October 1971

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education
National Center for Educational Research and Development
(Regional Research Program)

SE 013 404

Final Report

Project No. 0G058
Contract No. OEC-6-71-0475 (509)

Curriculum Design for Junior Life Sciences Based Upon the Theories of Piaget and Skinner

Ella Elizabeth Pearce

University of Houston

Houston, Texas

October 15, 1971

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education
National Center for Educational Research and Development

ACKNOWLEDGMENTS

This project reached completion through the combined efforts of several people. Special appreciation is expressed to the personnel of the public schools whose efforts made this project possible.

I wish to express gratitude to Dr. Silas W. Schirner, chairman of the Graduate Research Committee, whose assistance and support helped me to complete this project.

To other members of the research committee, Dr. Howard L. Jones, Dr. E. Alan Lohse, and Dr. Robert E. McClintock I wish to express my deepest gratitude for their counsel and support.

Gratitude is expressed to Mrs. Virginia Rhodes for making the drawings required for the description of the testing procedures and Mr. Tom Epley for constructing the experimental apparatus.

Appreciation is extended to the members of the judging panel: Dr. Silas W. Schirner, Dr. Howard L. Jones, and Dr. Robert E. Williams. Their efforts allowed for the establishment of construct validity of the curriculum materials.

I wish to express gratitude to Dr. and Mrs. T. C. Smith, Jr. whose personal support and encouragement was invaluable.

The research reported herein was performed pursuant to Project No. OG058, Contract No. OEC-6-71-0475 (509) with the

Office of Education, United States Department of Health, Education, and Welfare as authorized by P.L. 83-531, Cooperative Research Act, as amended by P.L. 89-10, Title IV, Sec. 2(a), Cooperative Research Program, Small Project Research.

CURRICULUM DESIGN FOR JUNIOR LIFE SCIENCES BASED UPON THE THEORIES OF PIAGET AND SKINNER

An Abstract of a Dissertation
Presented to
the Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

by
Ella Elizabeth Pearce
December 1971

Pearce, Ella Elizabeth. "Curriculum Design for Junior Life Sciences Based Upon the Theories of Piaget and Skinner." Unpublished Doctor's dissertation, University of Houston, December, 1971.

ABSTRACT

The present study had a twofold purpose. First, to develop experimental curriculum materials utilizing concrete and formal operations levels with secondary reinforcement to facilitate concept attainment in seventh grade life science. Second, to investigate these experimental curriculum materials to determine if they facilitated the learning of more science knowledge than in the current classroom learning situation and also facilitated the movement of students into the formal operations level of intellectual performance. The experimental curriculum materials were based upon the theory of intellectual development as couched by Piaget and the theory of secondary reinforcement postulated by Skinner. Contemporary life science conceptual schemes were organized to provide experiences appropriate for the abilities of the concrete operations students as well as the formal operations students present in the classroom. The materials consisted of seventeen related micro-units which encompassed one semester of school time.

Eight seventh grade life science classes were selected from four school systems in the metropolitan area of Houston, Texas, and were engaged in the study. Four classes, one from each district, were selected as the experimental group. These students used the experimental life science curriculum materials. The control group consisted of four classes, one chosen from each district. The control group did not use the experimental life science curriculum materials.

The sample used in the study consisted of nine students from each classroom (N = 72) which were selected and identified as being in the concrete operations stage of intellectual development by the pretest results. The data were collected and analyzed to measure the effects of the experimental curriculum materials in the areas of science achievement and intellectual performance. The _Metropolitan Science Test, Advanced Level_ was used to assess science achievement. Four Piagetian tasks were individually administered to each student in order to assess intellectual performance. The tests were administered in a pre-posttest situation.

The test results were analyzed by analysis of variance to evaluate the difference in performance between the experimental and the control groups for the two types of student outcomes. The chi square method was used to determine to what degree the differences between pre- and posttest results for intellectual performance within the experimental and the control groups were due to chance. To analyze the differences in intellectual performance change from pretest to posttest between the experimental and control groups, the _t_-test of differences was applied to the data. All tests were made at .01 level of significance. _Hartley's F-maximum Test_ for homogeneity of variance

revealed no marked heterogeneities on the scores obtained for science achievement and intellectual performance between groups.

There was no significant difference between the experimental and the control groups for science achievement. There was a significant difference between pre- and posttest results for each group. Thus, each group gained in science achievement, but the gains were not significantly different.

The experimental group demonstrated significant change in intellectual performance in the formal operations stage from pretest to posttest, while the control group did not indicate a significant difference in this area between pre- and posttest results. The comparison of the frequency of responses recorded in concrete operations and formal operations between pretest and posttest results indicated significant change for both groups tested. This significant change, indicated for the control group, did not represent entry into formal operations but represented gain from stage to stage within concrete operations (disequilibrium, Stage II-A to equilibrium, Stage II-B) and formal operations (disequilibrium, Stage III-A to equilibrium, Stage III-B) as noted by Inhelder and Piaget (1958).

A comparison of intellectual performance change from pretest to posttest indicated that the change for the experimental group was significantly greater than the change in intellectual performance for the control group for all four Piagetian tasks.

The results of this study indicate that students learned as much life science content in a curriculum designed for experiences in concrete and formal operations with secondary reinforcement as students in a "traditional" curriculum. The findings support the hypothesis that science experiences in concrete and formal operations facilitate the change of intellectual performance into the formal operations level. The findings give some evidence to support the theory that an active method of instruction which provides experiences for students to operate at their ability levels can be superior to the "traditional" method in providing experiences that facilitate the transition from concrete to formal operations level of intellectual performance.

It is suggested from the results of this study that further research could provide beneficial information. The suggested areas of investigation are: peer interaction influence on disequilibration of concrete operations students, teacher characteristics which enhance the change in intellectual performance, effect of secondary reinforcement media upon intellectual performance change, and curriculum materials designed to assimilate the effects of the formal operations students' role in peer interaction as a disequilibrating influence upon the concrete operations student.

TABLE OF CONTENTS

Page

LIST OF TABLES xiii

LIST OF FIGURES xiv

Chapter

1. THE PROBLEM AND DEFINITIONS OF TERMS 1

   THE PROBLEM 3

      Statement of the Problem 3

   DEFINITIONS OF TERMS 4

   RATIONALE FOR DEVELOPMENT OF THE CURRICULUM MATERIALS 11

2. REVIEW OF THE LITERATURE 14

   LITERATURE RELATED TO PIAGET'S THEORY OF INTELLECTUAL DEVELOPMENT 14

   LITERATURE RELATED TO SKINNER'S THEORY OF REINFORCEMENT 21

   LITERATURE RELATED TO THE PRACTICES OF SCIENCE INSTRUCTION 23

   A PEDAGOGY POSTULATED BY PIAGET 28

   SUMMARY 30

3. PROCEDURES 33

   DEVELOPMENT OF CURRICULUM MATERIALS 33

   FORMATION AND SELECTION OF TESTING INSTRUMENTS 35

      Science Achievement 35

      Piagetian Tasks 36

   DESCRIPTION OF TASKS 37

Chapter Page

SELECTION OF COMMUNITIES 39

SELECTION OF SUBJECTS 40

Selection of Groups 40

Selection of Sample 41

IMPLEMENTATION PROCEDURES 43

Teacher Contacts 43

Classroom Contacts 43

METHODS OF DATA ANALYSIS 44

SUMMARY 45

4. RESULTS AND INTERPRETATION 47

DEVELOPMENT OF CURRICULUM MATERIALS 47

SCIENCE ACHIEVEMENT PERFORMANCE 49

INTELLECTUAL PERFORMANCE IN FORMAL OPERATIONS 52

INTELLECTUAL PERFORMANCE IN CONCRETE OPERATIONS AND FORMAL OPERATIONS 55

INTELLECTUAL PERFORMANCE CHANGE 58

SUBJECTIVE EVALUATION OF CLASSROOM CONDITIONS 58

Experimental Conditions 58

Control Conditions 63

SUMMARY 64

5. DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS 66

DISCUSSION AND IMPLICATIONS 68

RECOMMENDATIONS 70

Page

BIBLIOGRAPHY 73

APPENDIXES 82

A. The Testing Instruments 83

B. The Teacher's Manual 92

C. The Sample Microunit 111

D. The Judging Procedures 120

E. Intellectual Performance in Formal Operations . . 141

LIST OF TABLES

Table	Page
1. Summary Table for Analysis of Variance for Science Achievement	50
2. Summary Table for Analysis of Variance for Intellectual Performance in Formal Operations	53
3. Response Frequencies for Intellectual Performance in Concrete Operations and Formal Operations	57
4. Intellectual Performance Change from Pretest to Posttest for Task 1, Task 2, Task 3, and Task 4	59
5. Means for Performance Change from Pretest to Posttest for Task 1, Task 2, Task 3, and Task 4	61
6. Intellectual Performance in Formal Operations (Stage III)	142

LIST OF FIGURES

Figure Page

1. Piagetian Task Profile 38
2. Piagetian Task Profile 42
3. Means for Science Achievement 51
4. Means for Intellectual Performance in Formal Operations 54
5. Experimental Apparatus 85
6. Experimental Apparatus 87
7. Experimental Apparatus 90

14

Chapter 1

THE PROBLEM AND DEFINITIONS OF TERMS

The decade of the 1960s marked a new serge of curriculum designs for the improvement of teaching elementary and secondary school science. These numerous curriculum designs evolved from a fury of activity generated by the technical race for supremacy among the world powers. This was part of the general swing of the educational pendulum away from the anti-intellectualism which for a time had pervaded American society (Henry, 1960).

Modern science curriculum designs were first instigated at the senior high school level. Private scientific and governmental agencies sponsored the new programs. Scientists, science educators, and classroom teachers collaborated in designing these "modern" programs. Designs for elementary science instruction were soon initiated and implemented in several schools by the mid-1960s. It was after the appearance of the high school and elementary programs that the junior high school level came into focus in curriculum design. The Intermediate Science Curriculum Study (ISCS) was initially designed to include physical science concepts for use in the seventh grade. Similar ISCS life science studies were designed for use in the ninth grade level.

This research study was concerned with the development, implementation, and evaluation of life science curriculum materials for use in the seventh grade of the junior high school science program. Life science is listed as a requirement for the completion of junior high school by a number of state education agencies.

The experimental materials designed for use in this study presented contemporary concepts from the life sciences in an interrelated framework congruent with modern learning theories. Two theoretical approaches to learning were utilized in the design of the curriculum materials. First, Piaget has described an intellectual transition from concrete operations to formal operations during the beginning of adolescence. Equilibrium of formal operations is reached during middle adolescence. Characteristic behavior responses are described for each stage of intellectual development (Inhelder & Piaget, 1958). Second, Skinner (1968) proposed that the most common way to reinforce human behavior in a learning situation is to tell the learner that the response made was a correct one. He advocated that a schedule of reinforcement increases productivity, interest, morale, and happiness of the learner.

Both the Skinnerian and Piagetian approaches were incorporated in the design of the laboratory experiences developed and used in this study. Experiences were provided for the intellectual ability of both the concrete operations student and the formal operations student in the seventh grade. Secondary reinforcement media were provided for students in both stages of intellectual ability.

THE PROBLEM

Statement of the Problem

There were two basic parts to this study. The first was to develop experimental curriculum materials utilizing concrete and formal operations levels with secondary reinforcement to facilitate concept attainment in seventh grade life science.

The second basic part was to use these experimental curriculum materials in an experimental situation to determine if their use enhanced the learning of science knowledge and facilitated the movement of students in the concrete operations level to the formal operations level of intellectual performance.

If the experimental curriculum materials do enhance the learning of science knowledge, then a class having used these materials should perform at a different level than a control class that did not use these materials. In an analysis of variance design involving a pretest and a posttest for an experimental group and a control group, this expectation of different performance would appear as a significant interaction when science achievement scores constitute the dependent variable.

If the experimental curriculum materials do facilitate the movement of students in the concrete operations level to the formal operations level, then a class having used these materials should perform at a different level than a control class that did not use these materials. In an analysis of variance design involving a pretest and a posttest for an experimental group and a control group, this expectation of different performance would appear as a significant interaction when frequency of formal operations responses constitutes the dependent variable.

The two hypotheses of interaction are tested in null form as a part of two analyses of variance in this study. The .01 level of significance is chosen for all statistical tests in the investigation.

DEFINITIONS OF TERMS

Behavior. An observable response to a stimulus emitted by an organism.

Concrete operations. The ability to structure thought on the basis of additive or multiple classifications. These elementary groupings of thought are systems of simple or multiple class inclusion or linkage. They do not include a combinational system linking the various given elements n-by-n. The mechanism of reversibility used by the subject consists of inversion or reciprocity, and the two are not integrated into a single system (Inhelder & Piaget, 1958).

In this study, the concrete operations student was identified by the type of behavioral responses demonstrated during the individual administration of four Piagetian tasks. The tasks were Task 1, Oscillation of a Pendulum and the Operations of Exclusion; Task 2, Falling Bodies on an Inclined Plane and the Disjunction Operations; Task 3, Combinations of Colored and Colorless Chemical Bodies; and Task 4, The Projection of Shadows (Inhelder & Piaget, 1958). When the characteristics of concrete operations in equilibrium were demonstrated, the student was identified as a concrete operator.

Concrete operations in disequilibrium (Stage II-A). During Task 1 the student could not serial order the four weights or isolate variables. The causal roles were attributed to the dropping point and the weight. During Task 2 the weight of the marbles cannot be isolated in respect to serial correspondence. Exact serial ordering of the slopes and length of bounds is demonstrated but no evidence is given to the separation of the two variables. During Task 3 the liquids are combined only by 1 + 2 + 3 + 4 + "g" or one solution with "g." Two-by-two combinations are not made. During Task 4 the serial ordering of the size of the rings and size of the shadows is demonstrated but the serial ordering is not related to the size of the shadows.

Concrete operations in equilibrium (Stage II-B). During Task 1 the student could serial order the weights but failed to isolate variables and identify the single causal variable. During Task 2 the student dealt with single variables (height and slope) but failed to formulate a correspondence between the two variables. During Task 3 the student demonstrated a two-by-two combinations or a three-by-three combination but failed to devise a systematic pattern of combination. During Task 4 the student established a correspondence between the sizes of the shadows thrown by the same ring and the increasing distances from the light source. Distance was calculated by starting from the screen rather than from the light source.

Control group. The four classrooms of seventh grade life science students who did not use the curriculum materials designed to provide experiences in concrete operations and formal operations with secondary reinforcement.

Equilibrium. The condition of thought where a system of balancing interactions and alterations with the structure of operational wholes being conserved while new elements are being added. Equilibrium is existent when operations, which the subject is capable of, constitute a structure such that these operations can be performed in either of three directions (by strict inversion, reciprocity, or negation). The total set of possible operations constitute a system of operations which compensate each other as far as they conform to reversibility (Piaget, 1950). In this study when the student could perform the operation with respect to reversibility the operation was identified as being in equilibrium. Concrete operations in equilibrium is referred to as Stage II-B. Formal operations in equilibrium is referred to as Stage III-B. The characteristics of both stages used in this study are described under concrete operations and formal operations in these definitions.

Experimental group. The four classrooms of seventh grade life science students who used the curriculum materials designed to provide experiences in concrete operations and formal operations with secondary reinforcement.

Formal operations. The organization of thought so the groupings of concrete operations are associated and integrated into a single combinational system. The n-by-n generalized classification becomes a set of all possible classifications compatible with the given base associations. The subject can see the "structured whole" of the n-by-n combinations. The mechanism of reversibility is such that the subject's thinking includes negation and reciprocity so integrated that reality is a function of possibility. Formal operations constitute the structure of the final equilibrium (Inhelder & Piaget, 1958).

In this study the formal operations student was identified by the type of behavioral responses demonstrated during the administration of four Piagetian tasks as previously noted in the definition of concrete operations. When characteristics of formal operations in equilibrium were demonstrated the student was identified as being in formal operations.

Formal operations in disequilibrium (Stage III-B). During Task 1 the student could separate variables, and with assistance from the investigator, could make combinations in which one variable varied while others remained constant. The combinations are not consistent. During Task 2 the student failed to separate the variables (height and slope), and confused height with distance being unable to separate the invariant height as the causal variable. During Task 3 the student established a systematic pattern of combinations. When 1 + 3 + "g" is combined and yellow occurred the student tried other combinations. During Task 4 the distance is calculated from the light source rather than from the screen. The student considered the distance between the light source and the first ring, and the verification of his solution is done with only one example where the shadows are of the same size.

Formal operations in equilibrium (Stage III-B). During Task 1 the student could isolate all variables present by varying a single variable while holding all others constant and then exclude all irrelevant variables. Proof was presented that the length of the string was the only relevant variable.

During Task 2 the student could determine the mutual compensation of slope and distance and isolate and verify the role of height as the causal variable. A law could be formulated with proof presented. During Task 3 the student could present the proof of the color by deductive conclusion. During Task 4 the student could formulate a generalized law and present proof.

Intellectual performance. The identification of behavioral responses demonstrated by the student during the individual administration of four Piagetian tasks. The student was identified as demonstrating intellectual performance in one of the following stages: concrete operations, Stage II-B (disequilibrium), Stage II-A (equilibrium); formal operations, Stage III-B (disequilibrium), Stage III-A (equilibrium) (Inhelder & Piaget, 1958).

Microunit. A series of related life science investigations designed to present concrete and formal operations experiences with secondary reinforcement.

Mobile equilibrium. The instability of concrete operations, mobile equilibrium, will be a variable acting to induce the thinking to formal operations. Concrete operations thought does not solve all of the problems raised by the interference of heterogeneous operations or intersections of different properties. To make use of this mobile equilibrium in the classroom the concrete operations student will encounter experiences in the curriculum materials which involve heterogeneous operations, intersecting of groupings, and extending the potential into the realm of possibility. The student will have the opportunities to realize gaps in his thinking. These gaps result from experiences within the curriculum materials and social interaction of the classroom environment (Piaget, 1950).

Operations. In this study operations were identified as being present in the thinking ability of the student when behavioral responses indicated an organizational pattern in the selection of the variables present in four Piagetian tasks in order to reach a solution to the problem.

Primary reinforcement. Any condition that satisfies a basic physiological need (Travers, 1967).

Reversibility: negation. The ability to isolate a variable in respect to its being present in experimental results in some cases and absent in others (Piaget, 1950).

Reversibility: reciprocity. The ability that allows an individual to eliminate a variable for the purpose of analyzing its role or to analyze variations on the other associated variables (Piaget, 1950).

Science achievement. The test score demonstrated by a student on the Metropolitan Science Test, Advanced Level.

Secondary reinforcement. A stimulus that was not originally a reinforcing one can become so through association with one that is reinforcing. These reinforcers derive their properties from having been associated with primary reinforcers (Travers, 1967).

In this study secondary reinforcement was provided by answers for the concrete operations solution and the formal operations solution for the same laboratory investigation. "Self-pacing" was included in the design of the curriculum materials.

RATIONALE FOR DEVELOPMENT OF THE CURRICULUM MATERIALS

Several "modern" science curriculum projects are similar in design to the curriculum materials used in this study. The Intermediate Science Curriculum Study is currently reaching completion. The scope of the materials ranges through grades seven, eight, and nine. The offerings for grade seven deal with physical science concepts written in "self-pacing" style which is tightly structured. The project includes computer assisted instruction (Lockard, 1970). Life science content is presented in grade nine of the program with much less structure than the preceding materials for grades seven and eight (Burkman, 1970).

The Biological Sciences Curriculum Study (BSCS), for use in the senior high school, was developed and evaluated during the years of 1959-1964. Glass (1964) reported, after a five year study of the project, that two features were stressed which had hithertofore been neglected in attempts to improve science instruction. These features were (1) large numbers of research scientists collaborated with high school teachers in replacing antiquated content with contemporary scientific knowledge, and (2) the new curriculum stressed the nature of scientific inquiry rather than the acquisition of scientific information.

The Science Curriculum Improvement Study (SCIS) was designed from the ideas of Piaget (Karplus & Thier, 1967). Piaget described four stages in the intellectual development from infancy to middle adolescence. The time and appearance of the stages varies with the individual. The overall design of the SCIS program was predetermined by the structures of science and the level of intellectual development as described by Piaget. The program encompassed kindergarten through grade six.

Similarities of this study to the above programs are evidenced in that contemporary science information as well as stages of intellectual development are included in the design of the experimental life science curriculum materials. Contributions to science instruction in the junior high school are necessary to provide a sequenced program throughout the entire educational system.

Student achievement in science has been studied by comparison of achievement between the "modern" curriculum designs and the "traditional" method for teaching science. This project attempted to make a similar comparison but added the study of adolescent cognitive development using Piagetian tasks.

Chapter 2

REVIEW OF THE LITERATURE

A search of current literature reported here is directed to research involving Piaget's theory of intellectual development and Skinner's theory of secondary reinforcement. This chapter is concluded with a brief review of the practices employed in science instruction in elementary and secondary schools and developments in pedagogy.

LITERATURE RELATED TO PIAGET'S THEORY OF INTELLECTUAL DEVELOPMENT

It is only within the past decade that American educational practices have been influenced to any degree by Piaget's theory of intellectual development. Piaget describes four intellectual stages of development in the child from infancy to middle adolescence. This review is confined to studies of concrete and formal operations.

Concrete operations are actions performed on objects to bring them together into classes of various orders or to establish relations between them. Class inclusions are performed by additive or multiplicative linkage only. These structures are based upon reversibility by inversion. The subject can add two contiguous classes together to form a single one (A + A' = B), or subtract a class from the whole formed by addition ($A = B - A'$). He can multiply two classes ($A_1 \times A_2 = A_1A_2$) or abstract one class formed in this way ($A_1A_2 : A_2 = A_1$). Relations can be handled by serial ordering, correspondences, and classification. The reversibility characteristic consists of reciprocity. But the combinational system formed by linking the elements n-by-n into a structured whole is absent in the thinking. Reciprocity and negation are not integrated into a single whole, thus the groupings remain isolated. It becomes evident that the concrete operations subject deals only with classifications, serial orders, and correspondences with the raw empirical data. He thinks only in terms of reality and is unable to project into the realm of possibility or use hypothetical deductive reasoning.

The concrete operations subject deals with class structures simply from an additive or multiplicative standpoint. Classes are structured by linkage which moves from one element to the next. Sparrow → bird → animal → living organism illustrates this type of linkage. This subject will simply continue to classify or order the data in a series because the ability to set up multiplicative associations and correspondences is not present in the thinking.

The ability to ascertain the occurrence of classes is illustrated by this example; $A_1A_2A_3$ are grouped (when A_3 represents a flexible circular bar) and the conclusion reached by the student is that A_1A_2 (inflexible brass rods) will not bend because they are not round. By this classification method the student is unable to completely isolate all variables and make the proper associations between them to demonstrate proof of a solution. The concrete operations student is limited to a simple registration of raw experimental results, forming only the classifications, serial ordering, and correspondences he thinks are sufficient for solving the immediate problem. This student will not demonstrate the ability to think beyond the observation of empirical correspondences. Contradictions and inconsistent results often arise for the concrete operations student and he cannot explain them with any degree of certainty (Inhelder & Piaget, 1958).

Inhelder and Piaget (1958) ascribed the chronological ages of seven through twelve to concrete operations. During this time concrete experience is developed, integrated, and altered into schemas. Equilibrium of concrete operations is established at about the age of twelve. Equilibrium is a mobile process within the thinking during this developmental stage. It is this concrete structure that forms the basis for the development of formal operations.

Formal operations emerge in adolescence. The subject is capable of formulating hypotheses from the basis of possibility and then returning to reality as a basis for proof. These hypothetico-deductive operations are expressed in propositions and logical constructions (disjunction, conjunction, and implication). This is evidenced in the manner in which experiments are carried out and the proofs presented. The formal operations are characterized by a higher degree of reversibility as contrasted to the concrete operations. Negation and reciprocity are integrated into a structured whole.

Piaget (1950) postulates that each organism is an open, self-regulating, active system. Equilibration is another factor which has a role in the intellectual development. The stages in the intellectual development represent a constant progression from a less to a more complete equilibrium and manifest the organism's steady tendency toward a dynamic integration. Therefore, equilibrium is an active set of compensations, not a final conclusion, but a new starting point to a higher form of mental development.

The Piagetian method of describing and studying the learning process is both flexible and coherent, and in a sense reconciles clinical and experimental approaches (Inhelder & Piaget, 1958). Aware of the disadvantages of pure observation on one hand and standardized tests on the other, Piaget adopted a method conducting free conversations with children and directing these conservations toward the nonexplicit regions of the child's thought. Sets of experimental apparatus are presented in interviews and the child verbally communicates his ideas while checking his working hypothesis in the manipulation of the sets of apparatus. His verbal results are evaluated qualitatively as to the type of thinking revealed by involvement in the problem situations.

A number of psychological investigators have tried to assess the validity of Piaget's studies. The overwhelming majority of studies reported have shown that the sequence of development as outlined by Piaget is an accurate portrayal of mental growth (Deutsche, 1937; Estes, 1956; Price-Williams, 1970; Dodwell, 1960; Flavell, 1963; Hunt, 1961; Elkind, 1961; Lovell, 1961).

There is supportive evidence that a predetermined sequence occurs in the growth of thinking ability and the child does not skip any of the developmental stages. A note of caution is injected as to age limitations of the developmental stages. Some research indicates that the mental age appears to be a more reliable indicator of Piagetian stages than chronological age (Hood, 1962; Carpenter, 1955; Laurendeau & Pinard, 1962). But, Piaget repeatedly emphasizes that the ages he uses are regarded only as guidelines or estimates (Piaget, 1950; Inhelder & Piaget, 1958).

Two major test standardization projects are being conducted, one in Geneva (Tuddenham, 1970) and the other in Montreal (Pinard & Laurendeau, 1964). Pinard is undertaking a longitudinal study encompassing two objectives: first, the validation of Piagetian task protocols; secondly, the building of a scale of mental development based on protocol data.

Equilibration is a process which Piaget evokes as the principal mechanism of transition from one stage in intellectual development to another. The intellectual structure is viewed as a system which is subject to modification through external intrusions. Equilibration is the mental process whereby the individual compensates for these intrusions through his own intellectual activity. New experiences which disturb the individual equilibrium at one level of intellectual structuring initiate the compensatory process of equilibration which terminates in a new level of structuring (Piaget, 1950; Palmer, 1970).

Smedslund (1961) used a training procedure to facilitate intellectual progress through the manipulation of states of equilibrium. A technique of inducing "cognitive conflict" was utilized in the acquisition of conservation of continuous amount. Gruen (1965) found a similar technique effective in the acquisition of conservation of number. Palmer (1970) reported results emphasizing that the presence of conditions which give rise to equilibration must be present in the facilitation of intellectual growth. Elkind (1961) has produced clear evidence that it is possible to bring about decentration (achieving increased mobility in equilibration) through training.

Confidence measurement may be another means of operationally defining equilibration (Shuford, Albert, & Massengill, 1966). Palmer (1967) found that characteristic levels of confidence may possibly be acquired through social transmission. If the conditions which initiate learning through problem solving provide the conditions which disturb the learner's equilibrium, it can be said that they would also disturb his confidence (Suchman, 1964).

Recent research does indicate that the child's mode of thinking is different than adult thinking. The proper utilization of time and tools can effect the educational process. Time refers to two aspects of the educational problem: first, the timing of educational experiences; and secondly, the necessity for realizing time variances in terms of time needed for individuals to acquire certain skills. Tools refer to the particular basic skills which are anticipatory of the child's adaptive requirements during later years. The important thing is to provide a variety of contents which will tap the variety of interests, cognitive level, and experential background of the child (Smock, 1968).

Ausubel (1964) outlined the possibilities and limitations for developing children's thinking. The concrete operations student is dependent upon concrete-empirical experience. When such experience is not available the student is unable to relate abstract propositions to the cognitive structure and hence they are devoid of meaning. According to Ausubel, abstract thinking emerges earlier in science because of the experiences afforded in manipulating ideas about mass, time, and space. Teaching can provide the necessary environmental stimulation suitable to the development of the child's thinking. As the students increase in age and cognitive capacity, teaching methods can place less emphasis on concrete empirical props. It is quite possible that prior understanding of certain concepts could be broadened at the formal, abstract level and this may be one way to discourage rote memorization.

A study comparing two methods of interpretation of scientific data in the classroom environment was conducted by Banks (1970). He concluded that modern secondary students should be encouraged to elaborate their own interpretations of scientific demonstrations rather than being presented with theories before the illustrations.

LITERATURE RELATED TO SKINNER'S THEORY OF REINFORCEMENT

Skinner (1968) advocated the application of secondary reinforcement to classroom teaching situations. A teaching sequence can be an arrangement of contingencies of secondary reinforcement because of which behavioral changes are evident. Students emit a response from the stimulus and are reinforced if this is the desired behavior. Undesired behavior receives no reinforcement in Skinner's technique.

In operant conditioning strengthening of behavior is done in the sense of making a response more probable or frequent.

The organism must be stimulated by the consequences of its behavior if conditioning is to take place (Skinner, 1957).

Behavior can be shaped or conditioned by reinforcement (Skinner, 1957). The reinforcement theory has been applied as a teaching technique in the design of programmed instruction. Chalmers, Holland, Williamson, and Jackson (1965) used programmed instruction to teach college students special skills in three-dimensional thinking required for understanding of crystallography. Hartley (1966) reported that in comparing programmed instruction with secondary reinforcement and conventional methods in terms of efficiency and achievement, 89 percent of the programmed materials were more effective.

Other types of programmed materials have been reported in the literature which demonstrate the effectiveness of reinforcement in behavior change. Instructional video tapes promoted college study skills (Neidt, 1967). Popham (1966) reported the effectiveness of computer instruction with immediate reinforcement in changing mathematical problem-solving behavior of fifth grade students. Results from several studies indicated that computer assisted instruction with reinforcement required less time for teaching and was just as effective as the conventional method (Longo & Cieri, 1969; Majer & Hansen, 1969; Schurdak, 1967).

Reward in the classroom was found to be effective in development of self-esteem (Bemis & Schroeder, 1969). Use of the WFF'N Proof game was described as a reinforcer in improvement of IQ (Allen, 1966). Effects of error correction in the classroom was investigated by Speiss, Thiel, and Leventhal (1969). They found that under all experimental conditions error correction produced significant learning results and that students who corrected their own errors demonstrated greater retention than students whose errors were corrected by a teacher.

Integration of the secondary reinforcement theory with Piaget's developmental theory of learning was expanded by Berlyne (1965). He made two modifications in the distinction of the Stimulus-Response schema: (1) transformation responses consist of transforming classical S-R responses (secondary reinforcement), and (2) internal reinforcement. Piaget (1964) equates transformation responses to operations and internal reinforcement to equilibration. Thus, there is a stimulus-response theory if operations and equilibration are included.

LITERATURE RELATED TO THE PRACTICES OF SCIENCE INSTRUCTION

Few areas of science instruction were designed to incorporate psychological approaches to learning prior to the decade of the 1960s. Curricula consisted of relevant readings, experiments, demonstrations, and other activities which created the functional understanding of science. Functional was defined as the child's ability to associate his relevant experience with scientific principles and to apply them to new but related experience (Mayer, 1961). The centering of curriculum on principles decompartmentalized the "traditional" distinctions between the sciences.

Before 1960 many textbooks were organized and written around the interdisciplinary principles of science. Science educators or classroom teachers designed and wrote these books to guide children in understanding science structure. These textbooks all shared the weakness of curriculum rigidity, because psychological knowledge was not used as a guide for grade placement of scientific concepts and principles. Some schools made multiple textbooks adoptions in an effort to avoid such rigidity (Kuslan & Stone, 1968). Most often the program, centered around the textbook, consisted of students' studying the book and performing related experiments. Outcomes were almost entirely factual information without knowledge of the processes of science (Mayer, 1961).

Generally, junior high school science instruction was entrenched in this rigid textbook oriented curriculum by 1960 (Henry, 1960). Currently, with the advent of more information about the learning processes of adolescence and an emphasis upon the need for creative and imaginative thinking in science curriculum design, junior high school science instruction is being modernized (Lockard, 1970).

The ISCS was developed as a comprehensive science program for the middle grades. The sequence features a gradual building of process skills and sequential development of basic science concepts. The pace and level of instruction can be adjusted to the ability, interests, and background of the students. A comprehensive field test of the materials has been conducted since 1966 involving 100,000 students in twenty-two states. Feedback from the total program is being used to develop the commercial versions of the program. An evaluation of the program is currently being prepared (Lockard, 1970; Burkman, 1970).

In 1967, BSCS began a program for the development of guidelines for a "modern" instructional sequence for junior high school life sciences. The focus was on the individual student from the chronological ages of twelve to fifteen years and his interests, needs, and societal responsibilities. The instructional materials are currently being developed (Mayer, 1970).

Several "modern" curriculum designs have been written for earth science, biology, chemistry, and physics. Over the past ten years, many studies have been concerned with evaluation of the various "modern" curriculum designs. The outcomes were classified according to knowledge (concept and content achievement), understanding scientific enterprise, and critical thinking ability.

Evaluation studies have been conducted which compared student outcomes in the "modern" high school science curriculum designs and in "traditional" approaches. In general, BSCS students seem to have greater retention of biology concepts and score higher on BSCS comprehensive tests than students in "traditional" courses. Little difference between outcomes on "traditional" tests for BSCS students and "traditional" students have been found (Montgomery, 1970; Lance, 1964; Lewis, 1966; Lisbonee & Fullerton, 1964; George, 1965).

Chemical Education Material Study (CHEM Study) and Chemical Bond Approach (CBA) were two "modern" chemistry instructional programs which were compared to the "traditional" approach to teaching. Altendorf (1966), Rainey (1964), and Anderson (1965) made comparisons of CHEM Study students with students enrolled in "traditional" chemistry. Their research indicated that CHEM Study students learned as much "traditional" chemistry as did students in "traditional" courses. Troxel (1968) compared CHEM Study, CBA, and "traditional" chemistry. CHEM Study and CBA students were found to perform significantly better in concept attainment than the "traditional" students.

Comparative studies have been made with physics curricula. Heath (1964) reported indications that Physical Sciences Study Committee (PSSC) students scored no higher than "traditional" students on "traditional" tests. Brakken (1965) found that PSSC students demonstrated greater improvement in critical thinking and numerical abilities than "traditional" students.

Schirner (1967) compared the outcomes of students enrolled in the Earth Science Curriculum Project (ESCP) with students in a "traditional" course. The compatibility of factors represented by teachers ID ratio, "traditional" versus "nontraditional" teachers, and type of course led to significant achievement in most student outcomes. The ESCP students tended to be better critical thinkers when compared with the "traditional" students. Each group scored significantly higher on the final examination suited to the type of course taught, ESCP students on the ESCP final and the "traditional" students on the general Earth Science Final.

The "modern" curriculum designs for use in elementary schools were evaluated with respect to numerous variables. The Elementary Science Study (ESS) was reported to produce improved reading and verbalization skills in ghetto children (Lockard, 1968). Stafford (1970) indicated that students enrolled in SCIS showed greater growth in six conservation tasks than did a control group. Haan (1968) presented evidence that the SCIS experience with Material Objects increased the experimental students' self-determination as contrasted with a control group of similar background.

The materials of Science - A Process Approach (SAPA) were used by Raun (1967) to investigate the interaction between curriculum variables and selected classroom student characteristics. He found limited evidence of significant grade differences between behaviors and performance strategies of science.

Numerous variables of the elementary science curricula undergoing evaluative procedures give evidence that the human factor is being injected into curriculum design. This philosophy was advocated by Combs (1969) as he related that too often curriculum design was concerned with subject matter. Glaser (1967) identified the need for opening new dimensions, defining more dependent effects, and establishing systematic procedures for longitudinal evaluation. Bloom (1967) suggested that evaluation should be as much concerned with environment as with appraisal of changes.

A PEDAGOGY POSTULATED BY PIAGET

Piaget (1970) stated, while addressing himself to educational practices, that practices employed in "traditional" education indicate that belief is held that sufficient experiences in experimental classroom training were provided by student observation of teacher demonstration of results of past experiments. But this method lacks experiences to excite the spirit of invention and training in the necessity for verifications of experiments. Piaget (1970) averred:

> . . . If the aim of intellectual training is to form the intelligence rather than stock the memory, and to produce intellectual explorers rather than mere erudition, then traditional education is manifestly guilty of a grave deficiency (p. 51).

According to Piaget (1970) students from eleven to fifteen are capable of conducting experiments while engaging in intellectual exploration. An active method of instruction for attainment of knowledge is possible because the two types of intellectual tools necessary for experimentation are possessed by these students. First, the tools of thought, consisting of operations in a combinative and propositional form; secondly, a particular method of procedure is rendered possible by the operations present. Knowledge consists of operative processes leading to a transformation of reality by actions or thought in order to grasp the mechanics and thus assimilate the objects and events into systems of operations. Experience may consist of logico-mathematical form where knowledge is derived from the actions that modify the objects or experiences may consist of actions upon objects to transform them in order to dissociate and vary factors. Operative or active methods of instruction which provide such experiences should be superior to the "traditional" approach.

Piaget (1970) further stated that Skinner's use of teaching machines is evidence of good psychology in that teaching machines make use of positive reinforcement and dispense with negative sanctions. The machines also point out the mechanical character of the teacher as conceived by the traditionalists. Since every discipline must include a certain amount of factual information, machines can shorten the time required for learning these facts. Perhaps with appropriate programming, machines can be one means of freeing the students and teachers from the rigidity of textbooks and allow more time for experimentation.

It is of fundamental importance to understand the structure of intellect before developing an instructional program. In addressing himself to education Piaget (1970) specified:

> . . . Although we cannot at present fix with any certainty the boundary between the contribution of the mind's structural maturation and that of the child's individual experience or the influences exerted by his physical and social environment, it does nevertheless seem that we should accept both that these two factors are constantly at work and that development is a product of their continuous interaction. From the point of view of schooling, this means, in the first place, that we must recognize the existence of a process of mental development; . . . that we should take into account the particular interests and needs of each stage. It also means, in the second place, that environment can play a decisive role in the development of the mind; . . . that sound methods can therefore increase the students' efficiency . . . (pp. 172-173).

SUMMARY

Many studies revealed that intellectual growth appears to progress through developmental stages as described by Piaget. Concrete operations were characterized by the ability to perform actions on objects to bring them together into classes or to establish relations between them. Formal operations were the ability to perform hypothetical deductive reasoning.

Previous studies also indicated that programmed instruction with secondary reinforcement produced more effective results in the learning sequence when compared to the "traditional" method. Other reinforcement media were reported to produce greater effects in development of self-esteem and improvement of IQ when compared to the "traditional" method.

Before 1960 science curricula were organized around textbooks designed to present principles without definite regard to learning theories. Several "modern" curriculum designs have now been written and implemented in senior high school and elementary school. Currently, only a few such "modern" science curriculum designs have been constructed for use in the junior high school program. These designs are presently being evaluated as to their effectiveness.

The high school science curriculum designs have been evaluated in the areas of content knowledge, critical thinking ability, and understanding the scientific enterprise. Results showed BSCS students scored higher on BSCS tests and scored equally as well as "traditional" students on "traditional" biology tests. CHEM Study students learned as much chemistry as "traditional" students in some of the reported studies, while other studies reported greater learning outcomes for the "modern" chemistry courses (CHEM Study and CBA). PSSC students, when compared with "traditional" students, produced significant improvement in critical thinking ability and learned as much physics content. ESCP students were better in critical thinking ability than the "traditional" students.

"Modern" elementary curriculum designs were evaluated with respect to particular objectives set forth in each design. Growth in conservation tasks was significant for SCIS students. Improvement of reading and verbalization skills were reported with ESS materials.

Student achievement in science has been studied by comparisons of achievement between the "modern" curriculum designs and "traditional" methods for teaching science in high school and elementary school. This project attempted to make a similar comparison but added the study of adolescent cognitive development using Piagetian tasks.

Chapter 3

PROCEDURES

In this study, an attempt was made to compare the results demonstrated by student achievement in two areas, science achievement and intellectual performance. The purpose of this chapter is to present a description of the procedures used to acquire the basic information on which the analysis was made. The procedures have been reported in the following categories:

1. Development of the curriculum materials
2. Formation and selection of testing instruments
3. Selection of communities
4. Selection of subjects
5. Implementation procedures
6. Methods of data analysis
7. Summary

DEVELOPMENT OF CURRICULUM MATERIALS

The seventh grade life science curriculum materials used in this study consisted of seventeen related microunits. The investigator developed the materials during a period of two years. During this period the microunits were taught by the investigator in a classroom setting and revised from student feedback.

Each microunit was organized around contemporary conceptual schemes for life science. Behavioral objectives were delineated for appropriate student outcomes. A series of investigations was organized to engage the students in controlling variables. These problem-solving experiences were designed for the two developmental levels of intelligence, described by Piaget, in which students typically operate at the ages of twelve and thirteen. The concrete operations student had opportunities to perform actions upon objects to bring them into classes of various orders or to establish relations between them. At the same time, the formal operations student was afforded opportunities to engage in hypothetical reasoning.

The microunits provided opportunities for students to be engaged in problem-solving situations. For example, Microunit XI, "Classification," Investigation 1 presented twenty insect specimen for classification. Grouping was done by the students on the basis of observed characteristics. No reference was made to classical classification. Investigation 2 provided twelve flowering plant specimen to be grouped by observed characteristics. Investigation 3 consisted of combining into a single system the classifications of Investigations 1 and 2 and adding five more plant and animal specimen into the classification hierarchy. Student justification for classification was recorded, allowing concrete and formal operations students freedom to respond according to their individual levels of thinking.

(Appendix C contains a copy of this microunit.)

Secondary reinforcement was provided by answer sheets which presented concrete and formal operations answers. The microunits were "self-pacing," another reinforcement factor. Social interaction was encouraged; group participation was required and group discussions among students and between student and teacher were frequent.

A panel of judges was selected to verify the investigator's ability to judge a student's responses to questions in the investigations as being in the concrete or formal stage. Their judgment of the experimental curriculum materials was used to establish construct validity of the materials. These judges were all familiar with the characteristics of concrete operations and formal operations. The materials were judged to establish whether the curriculum materials allowed responses for both the concrete operations student and the formal operations student during the problem-solving situations presented in the investigations. Appendix D presents a description of the judging procedures and a sample microunit which was judged for construct validity.

FORMATION AND SELECTION OF TESTING INSTRUMENTS

Science Achievement

One standardized test was used in this study for the assessment of science achievement. The test instrument was the

Metropolitan Science Test, Advanced Level, Form BM. This instrument was chosen because the content was believed representative of the abilities of seventh grade students. The content areas of the instrument are presented in Appendix A, Testing Instruments.

Piagetian Tasks

In order to assess the stages of intellectual development possessed by the students in the sample, four Piagetian tasks were administered to each of the students. These tasks were: Task 1, Oscillation of a Pendulum; Task 2, Falling Bodies on an Inclined Plane; Task 3, Combinations of Colored and Colorless Chemical Bodies; and Task 4, Projection of Shadows. These tasks are theoretically different from one another (Appendix A).

TESTING INSTRUMENT: PIAGETIAN TASK PROFILE

INTERVIEW PROTOCOL

During the individual administration of each Piagetian task the interview protocol consists of the investigator asking questions pertinent to the responses emitted by the subject. Verbal responses are clarified by these questions, therefore the responses can be coded for Concrete Operations and Formal Operations. The questions asked during the interview are: Why? How do you know? Can you solve the problem another way? Can you state a law? Can you prove that solution?

The behavioral characteristics of intellectual performance for each task are described for each stage. These characteristics, described by Piaget, are the basis for the assessment of responses emitted by the subject. Responses are coded for Concrete Operations and Formal Operations. The Piagetian Task Profile record is made for pretest and posttest responses. Figure 1 illustrates the Piagetian Task Profile.

DESCRIPTION OF TASKS

Task 1 involved students in a problem situation which required separation and exclusion of variables. Four different weights were each tied to strings of various lengths. The weights were attached to a ring stand and set into oscillation, by dropping and pushing each one to begin motion. Students were asked to determine if the weights oscillated at the same speed or different speeds and explain the reason for the answer. Successful solution of the problem required students to separate the variables involved and exclude the effects to determine that the length of the string was the causal variable.

The problem in Task 2 was to find the relationship between the height of the point from which a ball is released and the distance traveled before it comes to rest. Four marbles of varying weight and sizes were rolled down a moveable inclined plane. Since the distance traveled varied only as a function of

Figure 1

PIAGETIAN TASK PROFILE

A check mark is placed on the profile for each task, according to the stage indicated by the student's response.

NAME ____________________ CODE NUMBER ____________

SCHOOL ____________________ PRETEST ______ POSTTEST ______

		Task 1	Task 2	Task 3	Task 4
Formal	STAGE III-B				
	STAGE III-A				
Concrete	STAGE II-B				
	STAGE II-A				

the height of the release point, the successful answer required a distinction by disjunction between slope, distance, and height of release point. Slope and distance compensate each other and height can be distinguished as the causal factor.

Task 3 involved students in a situation where five colorless solutions were combined directly to establish a combinational system in relation to propositional logic. A certain combination of three solutions produced yellow. The successful answer demonstrated the yellow color with proof by deductive conclusion about the effects of other combinations.

A generalized law about the relative relationships between sizes of projected shadows and distances from the light source is the successful answer to Task 4. Students were asked to project two shadows of equal size on a screen using four rings of varying diameters. In order to reach the successful answer students had to generate, demonstrate, and present proof of a hypothesis.

SELECTION OF COMMUNITIES

Four school systems in the Houston, Texas, area consented to participate in the study. Two schools from each district were selected by an administrative official of each school district. The schools were selected because the respective students were similar in socioeconomic background and scholastic achievement record. One experimental and one control seventh grade life science classroom, chosen at random from each district, were involved in the study. The schools were as follows:

1. Deer Park Independent School District
   Experimental: Deer Park Junior High School
   Control: Deep Water Junior High School

2. Pasadena Independent School District
   Experimental: Southmore Intermediate School
   Control: Parkview Intermediate School

3. Spring Branch Independent School District
   Experimental: Spring Oaks Junior High School
   Control: Landrum Junior High School

4. Goose Creek Independent School District
   Experimental: Baytown Junior High School
   Control: Horace Mann Junior High School

SELECTION OF SUBJECTS

Selection of Groups

One classroom section of students enrolled in seventh grade life science from each school was selected for the study. Four classroom sections and their respective teachers were designated as the experimental group. These students were individually provided with a copy of the life science curriculum materials. Four different classroom sections and their respective teachers comprised the control group. The control group did not receive any of the materials designed by the investigator. All students were of middle class socioeconomic background and were of similar scholastic ability according to school records. Their chronological ages were such that they were expected to fall in the transition period from concrete operations to formal operations.

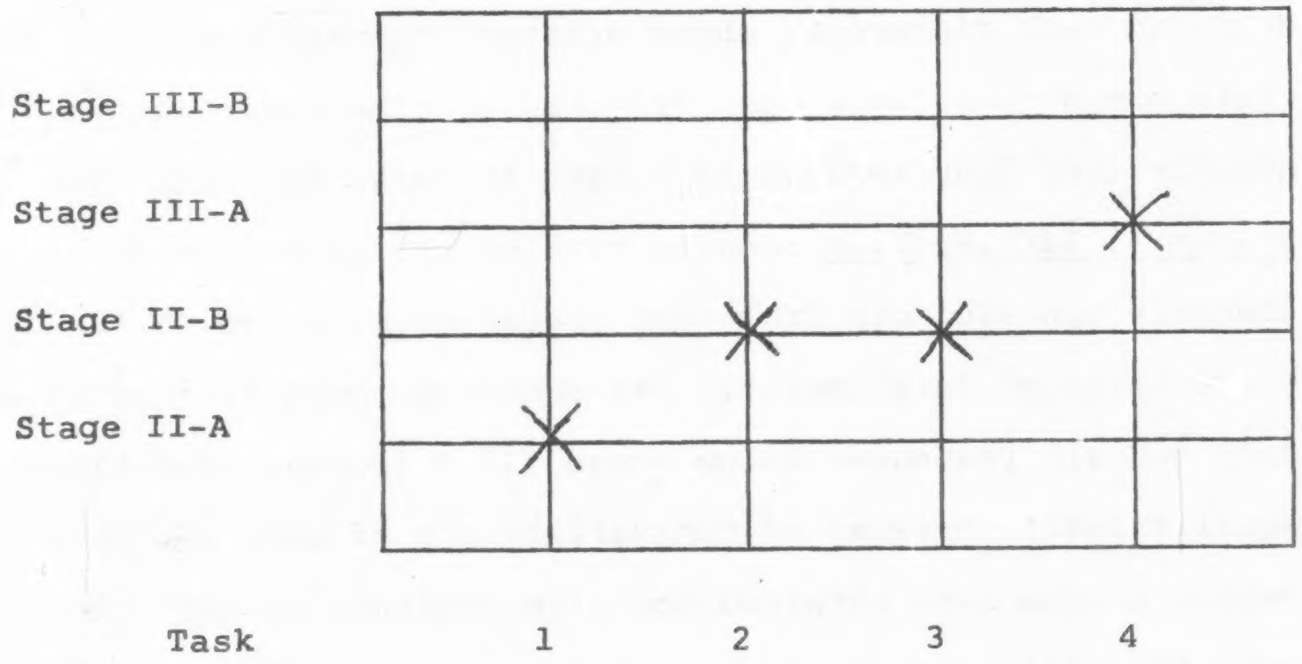
Selection of Sample

The population (N = 197) was screened to identify a concrete operations sample for purposes of evaluation. The screening consisted of administration of a written form of the Piaget correlation task (Inhelder & Piaget, 1958). Ten students in each classroom, whose written response indicated concrete operations, were then selected and the investigator administered four individual Piagetian tasks to them. The Piagetian Task Profile results enabled the investigator to identify ten students from each classroom as being in the concrete stage of development. The concrete operations level student had all responses below Stage III-B (formal operations in equilibrium). Because of nonavailability of some students, complete data were obtained for nine students in each classroom (N = 72).

The identification of the concrete operations sample was accomplished in the following manner. During the process of the administration of each of the four individual Piagetian tasks the behavioral responses were observed by the investigator and identified as being Stage II-A, Stage II-B, Stage III-A, or Stage III-B. The stage was coded on the Piagetian Task Profile in a pre-posttest situation. Figure 2 illustrates a Piagetian Task Profile. These key student responses were used to identify the stage. The expected responses have been previously described in the Development and Selection of the Testing Instruments reported in Chapter 3 of this study.

Figure 2

PIAGETIAN TASK PROFILE



Task 1. Serial ordering of weights was not accurate which indicated Stage II-A.

Task 2. Length of bound combined with height of slope as a causal factor without an isolation of height as a single factor indicated Stage II-B.

Task 3. The combination of 1 + 3 + "g" produced yellow and no attempt to make any further combinations indicated Stage II-B.

Task 4. Distance was calculated from the light source while only one shadow was produced which indicated Stage III-A.

IMPLEMENTATION PROCEDURES

Teacher Contacts

Initially, the four experimental teachers were given the teacher's manual (Appendix B) and teacher's copy of the curriculum materials. After the materials were reviewed, a meeting was held to discuss philosophy and implementation practices. It was emphasized that the role of the teacher was one of a resource person. Answer sheets were distributed and the discussion included instructions about their use in the classroom. Teachers were encouraged to motivate students in checking and correcting incorrect answers as part of the learning process. During the teaching semester individual conferences were conducted by the investigator with each teacher biweekly.

The four control teachers were not given any materials or instructions by the investigator. Individual discussions transpired between the investigator and individual teachers after each biweekly visit. This was done to equalize effects of the investigator upon the study.

Classroom Contacts

The investigator spent equal amounts of time in each of the four experimental classrooms. Each classroom was visited on an average of once every two weeks during the semester. During the visits the investigator observed instructional procedures, students' use of answer sheets, and social interaction within the classroom. Feedback sessions were conducted with the teachers to insure that the experimental procedure was followed.

Equal time was spent in control classroom visits by the investigator. Discussions between the teachers and the investigator were teacher initiated and directed.

METHODS OF DATA ANALYSIS

The hypotheses tested in this study were:

HO_1 There is no interaction between pre- and posttest science achievement measurements and classification into experimental and control groups.

HO_2 There is no interaction between pre- and posttest intellectual performance measurements and classification into experimental and control groups.

In the first major hypothesis stated above, the science achievement scores for each of the four conditions were subjected to a two-by-two mixed design analysis of variance; in addition to the hypothesis of interaction, this design also tested two null hypotheses for the main effects. The significance of main effects is of interest only when the interaction is found to be nonsignificant, and t-tests may be utilized to evaluate each main effect. If the interaction for this design is significant the main effects are not of interest; however, the simple effects (all possible comparisons among conditions) would be examined using appropriate techniques.

In the second major hypothesis stated the number of formal operations level responses for each subject is each of the four conditions were also subjected to a two-by-two design analysis of variance. The technique of interpretation parallels that described previously.

Hartley's F-maximum Test was used to evaluate the necessary assumption of homogeneity of variance for the analysis of variance design.

The Piagetian Task Profile results were examined for pre-posttest changes between Stage II-A, Stage II-B, Stage III-B, and Stage III-A. These changes were tallied for each of the four tasks in the experimental group and the control group. The total change was then tallied for the experimental group and the control group. The scores were analyzed by the t-test of differences.

SUMMARY

The curriculum materials for seventh grade life science were developed, implemented, and evaluated. Eight classrooms were selected for inclusion in this study. Four class sections in four schools comprised the experimental group. The control group consisted of four class sections in four schools, other than the experimental schools.

The experimental teachers were trained in implementation procedures for the life science curriculum materials. The investigator conducted classroom visits to insure that the implementation procedures were carried out. Equal time was spent in control classroom visits. Subjective evaluation of teaching practices for the experimental and control groups was recorded.

Two testing procedures were selected. Pre- and posttests were administered to both groups to evaluate science achievement and intellectual performance.

The data obtained on the pre- and posttests were analyzed to measure the effects of the life science curriculum materials on science achievement and intellectual performance.

Chapter 4

RESULTS AND INTERPRETATION

The purpose of this study was twofold; first, to develop effective materials and, second, to test experimentally these materials with groups of seventh grade students. The quality of materials was evaluated through analysis by expert judges. The effects of using these materials was evaluated through testing the null hypothesis for interaction in a mixed design analysis of variance.

DEVELOPMENT OF CURRICULUM MATERIALS

A microunit of materials (Appendix D) was presented to a panel of three judges. The decisions of the judges were based on the following criteria: (1) do experiences presented in the investigation provide opportunities for responses from both the concrete operations and formal operations students? (2) are answers (secondary reinforcement) appropriate for students from the concrete operations and the formal operations? and (3) was the rationale for the investigations in accordance with Piaget's description of concrete and formal operations?

A necessary condition for any valid use of data is the presence of objectivity and reliability in the original scoring. To provide an index of coder agreement, the technique suggested by Bernstein (1969) was selected. When Coder-1 and

Coder-2 have categorized the same elements, the estimate of agreement between them is defined as

$$P = \sqrt{a} \quad ,$$

where a is the percent of agreement in the two codings.

When Coder-3 has categorized the same elements, the estimates of objectivity are

$$P_1 = \sqrt{ab/c} \quad , \quad P_2 = \sqrt{ac/b} \quad , \text{ and } P_3 = \sqrt{bc/a} \quad ,$$

where a = percent of agreement between Coder-1 and Coder-2,

b = percent of agreement between Coder-1 and Coder-3,

c = percent of agreement between Coder-2 and Coder-3.

The predicted percent of correctness, when correctness on any element is defined as agreement by any two coders, may be estimated by m,

where $m = P_1P_2P_3 + P_1P_2Q_3 + P_2P_3Q_1 + P_1P_3Q_2$, $Q_1 = 1 - P_1$,

$Q_2 = 1 - P_2$, and $Q_3 = 1 - P_3$.

The use of these indices provides an estimate of the intercoder agreement.

The estimates of objectivity in classifying the micro-unit in this study were

$$P_1 = 0.94 \quad , \quad P_2 = 1.00 \quad , \quad P_3 = 0.94 \quad .$$

The predicted percent of correctness in classifying was 0.996. This very high degree of agreement is indicative of almost unanimous evaluative decisions by the members of the panel of judges. Therefore, agreement among judges was high enough to establish the construct validity of the developed curriculum materials.

SCIENCE ACHIEVEMENT PERFORMANCE

The first major hypothesis states in null form that there will be no interaction between pre- and posttest measurements and classification into experimental and control group. Table 1 presents a summary table for analysis of variance for science achievement scores. In the analysis of science achievement, as measured by the Metropolitan Science Test, Advanced Level, there was no significant interaction between test trials and conditions. The pretest mean for the experimental group was significantly higher than the pretest mean for the control group and the posttest mean of the experimental group was significantly higher than the posttest mean of the control group. There was a significant increase in mean level of performance from pretest to posttest for each group, the posttest being significantly superior for both groups. Figure 3 illustrates the composite means for science achievement for both groups.

From Table 1 it was seen that the hypothesized interaction was not present; therefore, the main effects were of interest in describing the nature of the data. The main effect of "conditions" was significant at the .01 level, indicating that the experimental group was significantly superior at both

Table 1

Summary Table for Analysis of Variance for Science Achievement

Source	SS	df	MS	F
Total	10299.2222	143		
Between Subjects	9202.2222	71		
Conditions	747.1111	1	747.1111	6.1853**
Error: Between	8455.1111	70	120.7873	
Within Subjects	1097.0000	72		
Trials	261.3611	1	261.3611	22.1598**
Trials X Conditions	10.0278	1	10.0278	0.8502
Error: Within	825.6111	70	11.7944	

** $p < .01$

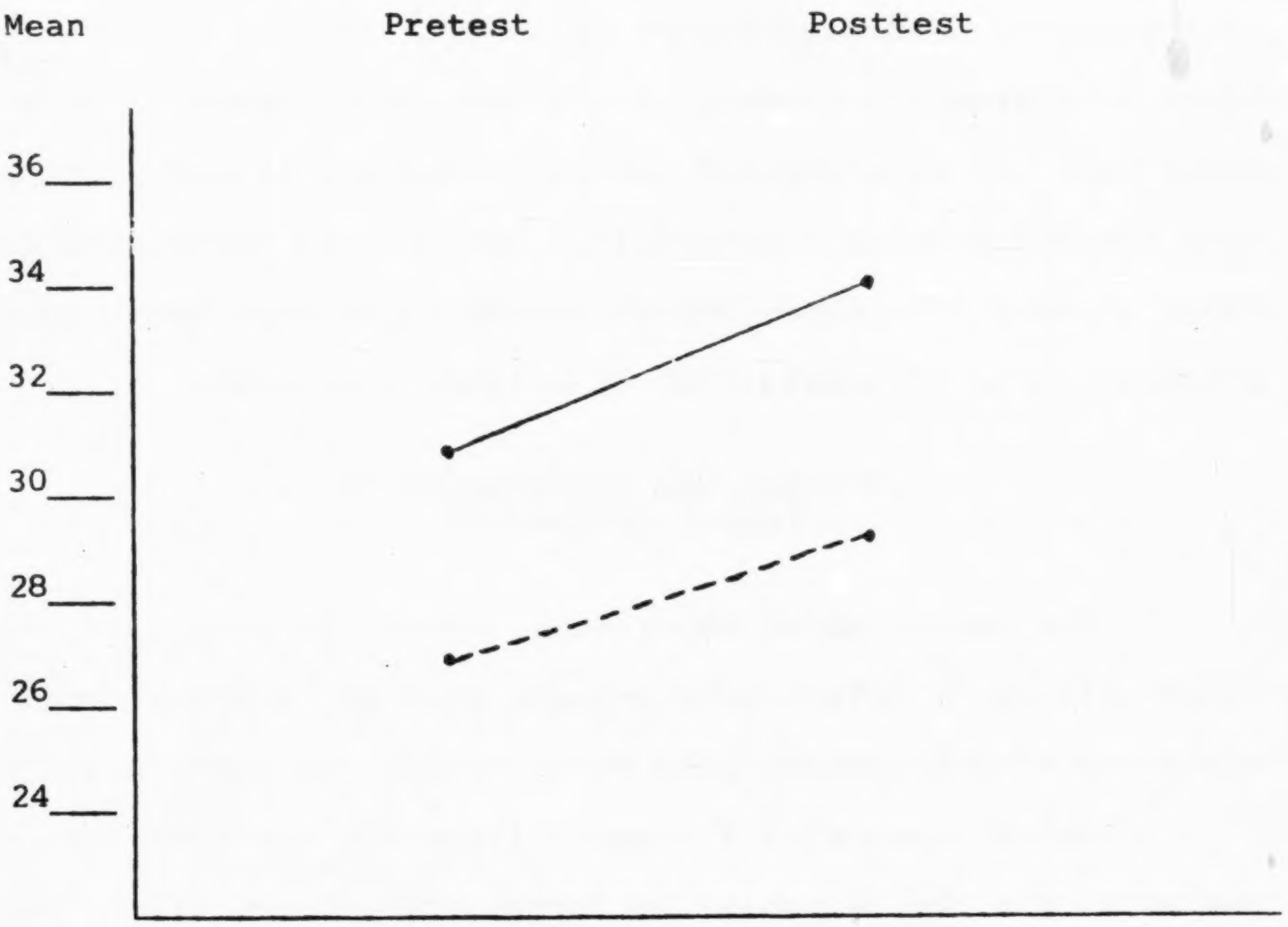


Figure 3

Means for Science Achievement

Experimental: ____ Pretest 30.81 Posttest 34.03

Control: ---- Pretest 26.78 Posttest 28.95

pre- and posttest trials. Figure 3 displays lines that are parallel within the bounds of chance, reflecting the lack of interaction. It is apparent that both experimental and control groups showed significant gains from pretest to posttest. Since both groups increased at the same rate, there is no evidence that the experimental materials had any effect different than the "traditional" materials. Both groups apparently gained equal amounts; the experimental materials neither enhanced nor hindered rates of acquisition of science knowledge.

INTELLECTUAL PERFORMANCE IN FORMAL OPERATIONS

The second major hypothesis states, in null form, that there will be no interaction between pre- and posttest measurements and classification into experimental and control groups.

Table 2 presents a summary table for the analysis of variance upon the responses in formal operations. From Table 2 it can be seen that a significant trials-by-conditions interaction existed at the .01 level. The significant main effects (conditions and trials) are not of interest in the light of significant interaction. The anticipated interaction related to movement from concrete to formal operations level was found to exist.

Figure 4 illustrates the nature of the significant interaction. At the time of the pretest the groups did not differ in mean number of responses at the formal operations

Table 2

Summary Table for Analysis of Variance for Intellectual Performance in Formal Operations

Source	SS	df	MS	F
Total	235.8889	143		
Between Subjects	61.8889	71		
Conditions	25.0000	1	25.0000	47.4382**
Error: Between	36.8889	70	0.5270	
Within Subjects	174.0000	72		
Trials	96.6945	1	96.6945	118.6290**
Trials X Conditions	20.2500	1	20.2500	24.8436**
Error: Within	57.0555	70	0.8151	

$^{**}p < .01$

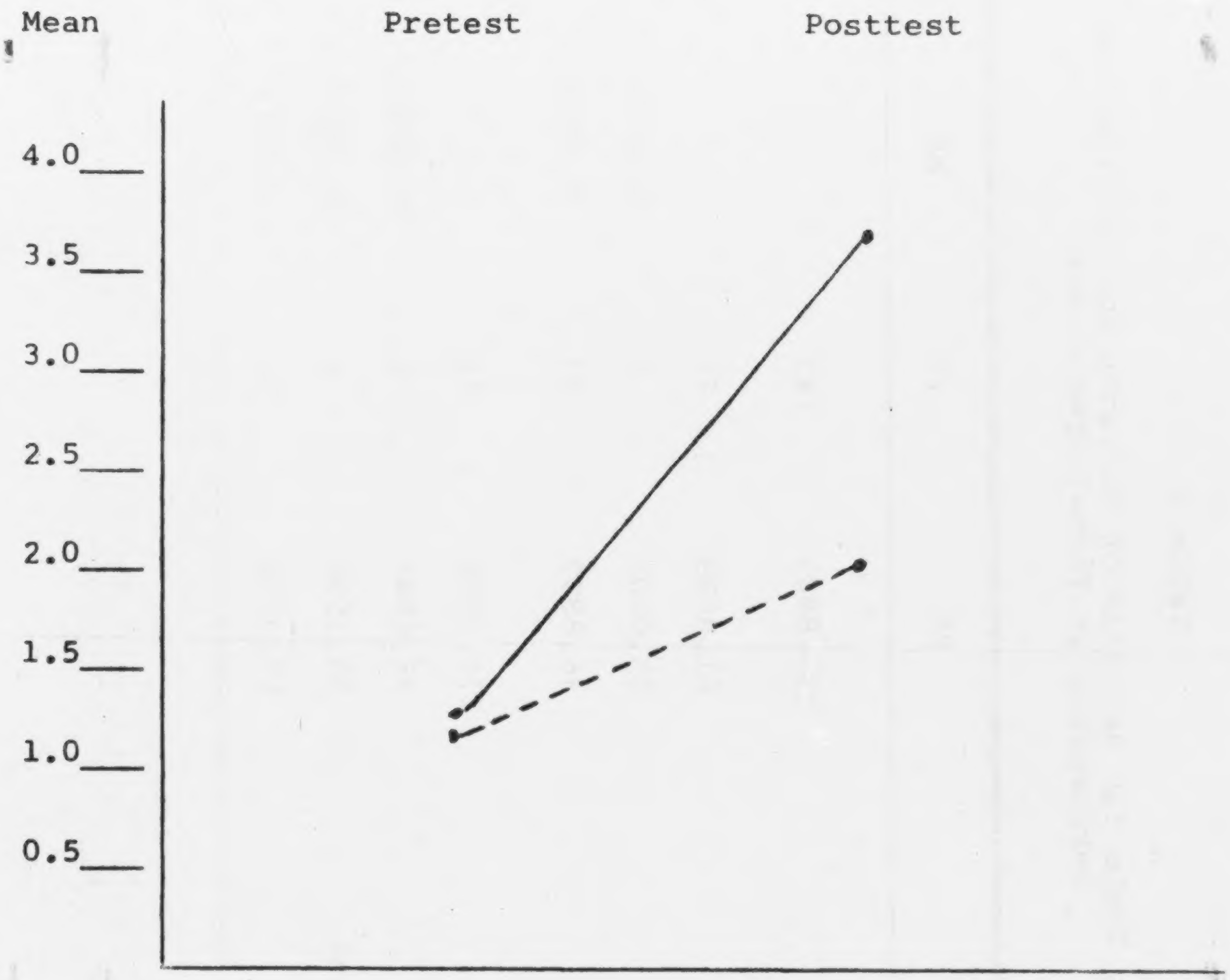


Figure 4

Means for Intellectual Performance
in Formal Operations

Experimental: ____ Pretest 1.25 Posttest 3.64

Control: ---- Pretest 1.17 Posttest 2.06

level. At the time of posttest, both groups had shown significant increases in mean responses; however, the experimental group increased at a significantly higher rate than did the control group. In Figure 4 the sharply different slopes for the two groups illustrates clearly the nature of this effect. The increase for the control group may be interpreted as the result of maturation and study using "traditional" science materials. The significantly greater change for the experimental group may be interpreted as the result of maturation plus a beneficial effect derived from the experimental materials. It may be concluded that the experimental materials did facilitate the movement of students in the concrete operations level to the formal operations level.

Appendix E provides individual response totals for intellectual performance in Stage III, formal operations.

INTELLECTUAL PERFORMANCE IN CONCRETE OPERATIONS AND FORMAL OPERATIONS

Having found a significant interaction upon data from the presence of all formal operations, it became desirable to know whether successive upward shifts were taking place among the sublevels of both Stage II (concrete operations) and Stage III (formal operations).

A chi square technique was used to analyze the relationship of the performance frequencies in concrete operations and formal operations between pretest and posttest results for the experimental group and the control group. Table 3 provides frequency of responses recorded for two stages of concrete operations and two stages of formal operations, pre- and posttest, for the groups.

The derived contingency coefficients of 0.556 for the experimental group, and 0.306 for the control group were found to be significant at the .01 level. The analysis revealed that the posttest results were significantly higher than the pretest results for each group. It should be noted that this gain in intellectual performance, although significant for the control group, represents gain from stage to stage inclusive of concrete operations (Stage II-A and Stage II-B) and formal operations (Stage III-A and Stage III-B) and does not represent entry into formal operations for the control students. For the experimental group, however, the higher posttest tallies do represent entry into formal operations. The data support not only the presence of formal operations level of intellectual performance, but also the presence of successive upward movement from concrete operations in disequilibrium to concrete operations in equilibrium to formal operations in disequilibrium to formal operations in equilibrium. The findings support Piaget's theoretical position on movement.

Table 3

Response Frequencies for Intellectual Performance in Concrete Operations and Formal Operations

Intellectual Performance	Conditions			
	Experimental		Control	
	Pretest	Posttest	Pretest	Posttest
Stage III-B	01	64	00	11
Stage III-A	44	66	42	63
Stage II-B	86	14	81	65
Stage II-A	13	00	21	05

Note: Stage II-A and Stage II-B are concrete operations. Stage III-A and Stage III-B are formal operations. Scores are tallied frequencies of responses.

71

INTELLECTUAL PERFORMANCE CHANGE

In Table 4 is presented the intellectual performance change from pretest to posttest for individual subjects in the experimental group and the control group. After finding the significant interaction between the two conditions for intellectual performance, a critical value of 2.66 for a t-test of differences was used as the critical ratio at the .01 level. Table 5 shows that the experimental group grand mean was 4.50 for performance change and the control group grand mean was 1.81 for all four tasks. Therefore, the experimental group produced a greater change in intellectual performance than did the control group. In all four tasks the change for the experimental group was significantly superior to the change for the control group. This was taken as evidence that all four tasks were sensitive to the effects of the experimental curriculum materials, and that in each case the experimental materials performed as hypothesized.

SUBJECTIVE EVALUATION OF CLASSROOM CONDITIONS

Experimental Conditions

The experimental students were actively involved in the learning process. Most students expressed enthusiastic behavior as they progressed through the microunits, but the degree of enthusiasm varied which indicated that some microunits were more interesting to them than others. The work

Table 4

Intellectual Performance Change from Pretest to Posttest for
Task 1, Task 2, Task 3, and Task 4

Experimental						Control					
Subject	T-1	T-2	T-3	T-4	Total	Subject	T-1	T-2	T-3	T-4	Total
1	+1	+1	+2	0	+4	37	0	+1	0	-1	0
2	-1	+1	+1	0	+1	38	0	+1	+1	-1	+1
3	0	+2	0	0	+2	39	0	0	+1	0	+1
4	0	+2	0	+1	+3	40	+2	+1	-1	0	+2
5	+1	+1	+1	0	+3	41	0	+1	+1	0	+2
6	+1	+1	+1	0	+3	42	-1	0	0	+1	0
7	+1	+2	+1	+1	+5	43	-1	0	0	0	-1
8	+1	+3	+2	+2	+8	44	0	0	+1	0	+1
9	+1	0	+1	+1	+3	45	0	0	+1	0	+1
10	+2	+1	+3	+2	+8	46	0	+1	0	+1	+2
11	+2	+2	+2	+1	+7	47	0	+1	+1	+1	+3
12	+1	+2	+2	0	+5	48	0	0	+1	+2	+3
13	+1	+1	+2	0	+4	49	0	0	+1	0	+1
14	+1	+2	+1	0	+4	50	0	+1	0	+1	+2
15	+1	+1	+2	0	+4	51	0	+1	0	+1	+2
16	+1	+1	+2	0	+4	52	+1	0	+1	+1	+3
17	+1	0	+2	+1	+4	53	+2	0	+1	0	+3
18	+2	0	+3	+1	+6	54	-1	0	+1	+1	+1
19	+1	+2	+1	+1	+5	55	0	+1	0	+2	+3
20	+1	+2	+2	+2	+7	56	0	0	+2	0	+2
21	+1	+2	+2	0	+5	57	+1	0	+1	+1	+3
22	+1	+2	+2	0	+5	58	+1	0	+1	+1	+3
23	0	+1	+2	+2	+5	59	+1	+1	+2	0	+4
24	+2	+1	+2	+2	+6	60	0	+1	0	+1	+4
25	+1	+2	+1	+2	+6	61	+1	+1	+1	+1	+4

73

Table 4 (continued)

Experimental						Control					
Subject	T-1	T-2	T-3	T-4	Total	Subject	T-1	T-2	T-3	T-4	Total
26	+2	+1	+1	+1	+5	62	+1	0	+1	+1	+3
27	+1	+1	+2	+1	+5	63	+1	0	+1	+1	+3
28	+1	+3	+2	0	+6	64	0	+1	-1	-1	-1
29	0	+2	+2	+1	+5	65	-1	-1	0	0	-2
30	+1	0	+1	0	+2	66	0	+1	0	0	+1
31	+1	+2	+1	0	+4	67	+2	+1	+1	0	+4
32	+1	+1	+1	0	+3	68	+1	+1	+1	0	+3
33	+1	+2	0	0	+3	69	0	+2	+1	+1	+4
34	+1	0	+2	+1	+4	70	+1	+1	+1	0	+3
35	+1	+2	+1	+1	+5	71	0	+1	0	-1	0
36	+1	+1	0	0	+2	72	0	+1	+1	+1	+3

Note: + indicates gain in developmental levels (Stages II-A--III-B), pretest to posttest; - indicates loss in developmental levels from pretest to posttest; and T refers to task.

Table 5

Means for Performance Change from Pretest to Posttest for Task 1, Task 2, Task 3, and Task 4

Conditions	Mean				Total
	Task 1	Task 2	Task 3	Task 4	
Experimental	0.972	1.361	1.472	0.694	4.500
Control	0.277	0.556	0.611	0.361	1.805

with the microscope and ecological study plots appeared to be most popular. Dissection, possibly, was the least popular. These decisions were based upon teacher observations and student feedback.

Of particular interest was the influence of the reinforcement media. Initially, teachers reported difficulties in trying to implement the use of the answer sheets in that the students would copy answers. In order to surmount this difficulty the teachers used a conditioning process. Assistance, in the form of questions as to: Why? How? What is the proof for your solution? was given by the teachers as the students worked in groups. After the students' behavior reflected self-confidence they used the answer sheets as guides only and corrected their mistakes.

Self-pacing was another reinforcement media. The students had to be encouraged to become responsible for their own learning. The teachers used various techniques to encourage responsibility. The investigator was aware of this difficulty and offered suggestions upon request from the teachers. The teachers reported that most of the students seemed to develop a sense of responsibility during the semester. Peer relationships appeared to be influential in development of confidence and responsibility. Teachers reiterated examples of group interaction where student initiated discussions were conducted. The students who produced formal operations answers from the investigations seemed to induce "cognitive conflict" conditions in their concrete operations peers by asking questions and requesting explanations.

Teachers provided textbooks and resource materials for student use. The teachers noted that students were self-motivated in the use of these materials.

Evaluation of concept attainment was the decision of the teachers. Some teachers administered tests based upon the behavioral objectives while others recorded grades from the student answers in the microunits. The investigator was not involved in this type of evaluation for report card records.

Students provided feedback information. The most common remark made was: "This course makes me think. I cannot find answers in a book."

Control Conditions

The control teachers used an instruction sequence based upon the state adopted textbook. Lecture-demonstration was the instructional method utilized by three of the four teachers. The students were required to record lecture notes, answer textbook questions, and keep this material in a notebook. The students were given periodic tests over the textbook and notebook information.

Teachers supplemented the textbook with films and filmstrips. Factual information was recorded by the students in their notebooks, as the teacher directed, during the viewing sequence. Very few laboratory exercises were provided for student participation. Generally, laboratory experience consisted of observations of teacher demonstrations. A teacher-directed discussion followed such demonstrations and students were encouraged to participate in the discussions.

The other control teacher used a combination of instructional methods. The textbook was used as an organizational framework in that students read assignments and answered questions, which were compiled in a notebook. Test questions came from this material. This assigned work could be done at home or in class. During class sessions the students were encouraged to work on projects of their individual choice. Some of these projects consisted of making shell and insect collections, growing plants, and conditioning hamsters. Audiovisual materials and reference books were available for the students to use.

SUMMARY

Interjudge agreement was found to be significantly high. Thus, it was inferred that construct validity was present in the experimental life science curriculum materials.

Contrary to expectations, no difference was found in the manner in which experimental and control subjects performed in science achievement. It was concluded that the experimental materials neither enhanced nor hindered levels of performance as measured by the Metropolitan Science Test, Advanced Level.

As predicted, there was a significant interaction between testing trials and experimental conditions. It was concluded that use of the experimental materials facilitated movement from the concrete operations level into the formal operations level. The movement was found to be complex and hierarchical in nature. The stages described by Piaget were found to be affected in sequence by the experimental materials. All four of the tasks appeared to be significantly influenced by the experimental materials.

Chapter 5

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

Research concerned with Piaget's theory of intellectual development indicated that children do evolve through certain characteristic stages of intellectual development as they mature chronologically. Actions are internalized and regulated in the cognitive structure and this equilibration process terminates in a new level of thought. Indications were reported that secondary reinforcement of desired behavior does help to enhance the learning process. Learning theories and contemporary science information were used in the designing of many "modern" science curriculum designs. Evaluation of these programs indicated that the students learned as much science information as students enrolled in the "traditional" mode of science instruction. Considerable evidence, as pointed out in Chapter 2, has been reported to support the two theoretical views and the development of "modern" science curriculum design.

The present study had as its primary purpose the comparison of experimental curriculum materials for seventh grade life science with the "traditional" mode of teaching. All subjects were in the concrete operations and formal operations stages of intellectual development. The data related to the effects in science achievement and intellectual performance.

It was the opinion of the investigator that information about adolescent learning would add another dimension to knowledge about "modern" science curriculum design for the junior high school.

A sample of seventy-two subjects was selected from four public school systems in the Houston area. The experimental group was comprised of nine students enrolled in each of four schools, one school being in each district. The control group was comprised of another thirty-six students enrolled in four separate schools, nine students were used from each of the schools. The two groups were in eight separate schools. The experimental group used the experimental life science curriculum materials and the control group did not use the materials.

The research instrument for evaluating science achievement was the Metropolitan Science Test, Advanced Level. For the evaluation of intellectual performance the Piagetian Task Profile was used.

To analyze the relationships of the experimental and control groups two testing procedures were used. The following tests were each administered in a pretest, posttest situation. The Metropolitan Science Test, Advanced Level was administered to each group for the area of science achievement. Four individual Piagetian tasks were administered, individually to each subject, for the evaluation of intellectual performance. The responses were coded on the Piagetian Task Profile.

Contrary to expectation, no evidence was found to indicate that the experimental materials enhanced or hindered acquisition of science knowledge. As predicted, it was found that the experimental materials facilitated movement for students in the concrete operations stages into the formal operations stages of intellectual performance.

DISCUSSION AND IMPLICATIONS

The results of this study indicate that students learn as much science content in a curriculum designed for experiences in concrete operations and formal operations with secondary reinforcement as students in a "traditional" curriculum. The findings support the hypothesis that science experiences in concrete operations and formal operations with secondary reinforcement facilitate the change of intellectual performance into the formal operations level. It was interesting to note that the change in overall intellectual performance was greater for the experimental group. These findings give some evidence to support the theory that an active method of instruction which provides experiences for students to operate at their ability levels can be superior to the "traditional" method in providing experiences that facilitate the transition from concrete to formal operations stage of intellectual development.

The present study presented a comparison of science achievement and intellectual performance. The results of this study may be influenced by the initial differences in science achievement and intellectual performance. There was no means by which the investigator could ascertain if these initial differences in either one or both of the factors contributed to observed changes after treatment. Several other questions remain unanswered. Were the experience differences indicated in science achievement a factor which influenced the more rapid transition of the experimental group from concrete operations into formal operations of intellectual performance, rather than the experimental curriculum materials? Perhaps, with the administration of additional Piagetian tasks, this question could be investigated. Is the peer interaction between concrete operations students and formal operations students a factor which affected the transition into formal operations level of intellectual performance? Did this initial difference in science achievement on the pretest scores between the experimental and control groups indicate an experience difference which influenced peer interaction within the experimental group, in that students were capable of attaining formal operations more rapidly, and this peer influence affected the transition of the concrete operations sample? This question may be important, because a fully formal operations sample could not be identified by the screening technique used in the present study. Another question which remains unanswered in the present study is related to the effect of the secondary reinforcement media in the facilitation of change in intellectual performance. Both groups demonstrated significant change in intellectual performance from pretest to posttest, but the change for the experimental group was greater in each Piagetian task. Were the secondary reinforcement media a factor which combined with peer interaction and influenced this more rapid change in intellectual performance for the experimental group?

RECOMMENDATIONS

The present study suggests that considerable information might be obtained by the exploration of the equilibrium process that occurs during intellectual development into formal operations. Investigations could be conducted which would give insight into the actual science experiences which disequilibrate the concrete operations students and induce intellectual performance in formal operations. Longitudinal studies could be conducted to investigate the effects of peer interaction upon intellectual performance. Information about peer interaction could be obtained by investigating the classroom learning situation where the formal operations students are identified at the outset of the study. The peer interaction could be identified as to formal operations students interacting with concrete operations students during the learning situation. This type of longitudinal study could yield information identifiable with the peer interaction influence of the formal operations students, especially if the comparison was made between heterogeneous grouping (concrete with formal operations) and homogeneous grouping (concrete with concrete operations and formal with formal operations) in the classroom learning situation. Perhaps curriculum materials could be designed to accommodate the effects of the formal operations students' role in peer interaction as a disequilibrating influence upon the concrete operations students.

Implications of such future research would seem to be that teacher characteristics should be studied to identify those teacher behaviors which correlate with intellectual performance changes in students. Encouraging self-confidence in problem solving is a teacher characteristic which appears to be significant in the classroom environment. Studies could be conducted to investigate the relative influence of the effects of teacher and student interaction and peer interaction upon intellectual performance. Perhaps with more information about how the adolescent learns a more clear identification can be made for the product of the educative system.

There is ample evidence that applying the secondary reinforcement elements suggested by Skinner to materials constructed with reference to the developmental stages described by Piaget can be effective in modifying the mode of approach to problems in science. It appears that materials constructed upon these principles do not adversely affect the acquisition of "traditional" content. Insofar as materials similar to those used in the present study can lead to higher levels of intellectual operations while retaining "traditional" content, it is obvious that science instruction in the junior high school can only advance by adopting the proposed approach to curriculum design.

BIBLIOGRAPHY

BIBLIOGRAPHY

Allen, L. E., Allen, R. W., & Miller, J. C. Programmed games and the learning of problem-solving skills: the WFF'N proof example. Journal of Educational Research, 1966, 60, 22-26.

Altendorf, J. J. A study of student achievement in high school chemistry using CHEM Study and conventional approaches. Dissertation Abstracts, 27:01A:45, July, 1966.

Anderson, J. S. A comparative study of chemical education material study and traditional chemistry in terms of students' ability to use selected cognitive processes. Dissertation Abstracts, 25:09:5147, March, 1965.

Athey, I. J., & Rubadeau, D. O. (Eds.) Educational implications of Piaget's theory. Waltham, Mass.: Ginn-Blaisdell, 1970.

Ausubel, D. P. The transition from formal to abstract cognitive functioning: theoretical issues and implications. Journal of Research in Science Teaching, 1964, 2, 261-266.

Ausubel, D. P. Educational psychology, a cognitive view. New York: Holt, Rinehart & Winston, 1968.

Banks, S. H. How students in a secondary modern school induce scientific principles from scientific experiments. In I. F. Athey and D. O. Rubadeau (Eds.), Educational implications of Piaget's theory. Waltham, Mass.: Ginn-Blaisdell, 1970.

Beard, R. M. An outline of Piaget's developmental psychology for students and teachers. New York: Basic Books, 1969.

Bemis, K. A., & Schroeder, G. B. Effects of varying quality, amount, and delay of reward in the classroom. In V. Crockenberg (Ed.), American educational research association, paper abstracts. Washington, D. C.: American Educational Research Association, 1969.

Bernstein, Allen L. An estimate of the accuracy (objectivity) of nominal category coding. In V. Crockenberg (Ed.), American educational research association, paper abstracts. Washington, D. C.: American Educational Research Association, 1969.

Berylne, D. Structure and direction in thinking. New York: Wiley, 1965.

Bloom, B. J. Taxonomy of educational objectives, handbook I: cognitive domain. New York: David McKay, 1956.

Bloom, B. J. Toward a theory of testing which includes measurement-evaluation-assessment. From the Proceedings of the Symposium on Problems in the Evaluation of Instruction, December, 1967. CSEIP Occasional Report No. 9. Los Angeles: University of California, Center for the Study of Instructional Programs. (Offset.)

Brakken, E. Intellectual factors in PSSC and conventional high school physics. Journal of Research in Science Teaching, 1965, 3, 19-25.

Bruner, J. S. Toward a theory of instruction. New York: W. W. Norton, 1968.

Burkman, E. Intermediate science curriculum study. In Course and curriculum improvement projects. (NSF Rep. No. 0-389-256) Washington, D.C.: United States Government Printing Office, 1970.

Carpenter, T. E. A pilot study for quantitative investigation of Jean Piaget's original work on concept formation. Educational Review, 1955, 7, 142-149.

Chalmers, B., Holland, J., Williamson, R., & Jackson, K. Crystallography, a programmed course in three dimensions. New York: Appleton-Century-Crofts, 1965.

Colton, R., & Butts, D. The role of classification skills in acquisition of concrete operational thought. In Abstracts of presented papers, National Association for Research in Science Teaching, 44th Annual Meeting, Silver Springs, Maryland, March, 1971.

Combs, A. W. The human factor in the current curriculum. In H. L. Jones (Ed.), Curriculum development in a changing world. Syracuse: Syracuse University Press, 1969.

Deutsche, J. M. The development of children's concepts of causal relations. Minneapolis: University of Minnesota Press, 1937.

Dodwell, P. Children's understandings of number and related concepts. Canadian Journal of Psychology, 1960, 13, 191-203.

Durost, W. N., Bixler, H. H., Hildreth, G. H., Lund, K. W., & Wrightstone, J. W. Metropolitan science test, advanced level manual for form bm. New York: Harcourt, Brace & World, Inc., 1960.

Elkind, D. The development of quantitative thinking: a systematic replication of Piaget's studies. Journal of Genetic Psychology, 1961, 98, 37-46.

Estes, B. W. Some mathematical and logical concepts in children. Journal of Genetic Psychology, 1956, 88, 219-222.

Ferguson, G. A. Statistical analysis in psychology and education. (2nd ed.) New York: McGraw-Hill, 1966.

Flavell, J. H. The developmental psychology of Jean Piaget. Princeton: D. Van Nostrand, 1963.

George, K. D. The effect of BSSC and conventional biology on critical thinking. Journal of Research in Science Teaching, 1965, 3, 293-299.

Glaser, R. Theory of evaluation of instruction: changes and trends. From the Proceedings of the Symposium on Problems in the Evaluation of Instruction, December, 1967. CSEIP Occasional Report No. 13. Los Angeles: University of California, Center for the Study of Instructional Programs. (Offset.)

Glass, B. Renascent biology: a report on the AIBS biological sciences curriculum study. In R. W. Heath (Ed.), New curricula. New York: Harper & Row, 1964.

Glass, G. V. (Ed.) Curriculum. Review of Educational Research, 1969, 39, 3, 283-375.

Gruen, G. E. Experiences affecting the development of number conservation in children. Child Development, 1965, 36, 963-980.

Haan, N. A study of SCIS children's belief in self determination. In R. Karplus (Ed.), What is curriculum evaluation? Six answers. Berkeley: University of California, 1968.

Hartley, J. Research report. New Education, 1966, 2, 29-41.

Heath, R. W. Comparison of achievement in two physics courses. Journal of Experimental Education, 1964, 32, 348-354.

Henry, N. B. (Ed.) Rethinking science education. Part I. The fifty-ninth yearbook of the national society for the study of education. Chicago: University of Chicago Press, 1960.

Herron, J. D. Evaluation and the new curricula. Journal of Research in Science Teaching, 1966, 4, 159-170.

Hood, H. B. An experimental study of Piaget's theory of the development of numbers in children. British Journal of Psychology, 1962, 53, 273-286.

Hunt, J. M. Intelligence and experience. New York: Ronald Press, 1961.

Inhelder, B., & Piaget, J. The growth of logical thinking: from childhood to adolescence. New York: Basic Books, 1958.

Jones, H. L. (Ed.) Curriculum development in a changing world. Syracuse: Syracuse University Press, 1969.

Karplus, R., & Thier, H. D. A new look at elementary science. Chicago: Rand McNally, 1967.

Kuslen, L. I., & Stone, A. H. Teaching children science: an inquiry approach. Belmont, Calif.: Wadsworth, 1968.

Lance, M. L. A comparison of gains in achievement made by students of BSCS high school biology and students of a conventional course in biology. Dissertation Abstracts, 25: 9:5147-5148, November, 1964.

Laurendeau, M., & Pinard, A. Causal thinking in the child. New York: International Universities Press, 1962.

Lewis, W. A. An evaluation of four selected approaches to teaching high school biology. Dissertation Abstracts, 27: 06A:1689, December, 1966.

Lindquist, E. F. Design and analysis of experiments. Boston: Houghton Mifflin, 1953.

Lisbonee, L., & Fullerton, B. J. The comparative effects of BSCS and traditional biology on student achievement. School Science and Mathematics, 1964, 64, 594-598.

Lockard, J. D. (Ed.) Sixth report of the international clearinghouse of science and mathematics curricular developments. College Park: Science Teaching Center, University of Maryland, 1968.

Lockard, J. D. (Ed.) Seventh report of the international clearinghouse on science and curriculum developments. College Park: Science Teaching Center, University of Maryland, 1970.

Longo, A. A., & Cieri, V. P. The feasibility of computer assisted instruction in U.S. Army Base electronics training. In V. Crockenberg (Ed.), American educational research association, paper abstracts. Washington, D.C.: American Educational Research Association, 1969.

Lovell, K. A follow-up study of Inhelder and Piaget's the growth of logical thinking. British Journal of Psychology, 1961, 52, 143-153.

Majer, K., & Hansen, D. A study of computer-assisted, multimedia instruction augmented by recitation sessions. In V. Crockenberg (Ed.), American educational research association, paper abstracts. Washington, D.C.: American Educational Research Association, 1969.

Maltzman, I. On the training of originality. Psychological Review, 1960, 2, 29-42.

Markel, B. Empirical testing of programs. Programmed instruction. Sixty-sixth yearbook of the national society for the study of education. Chicago: University of Chicago Press, 1967.

Marshall, J. S. The future of science education. In H. L. Jones (Ed.), Curriculum development in a changing world. Syracuse: Syracuse University Press, 1969.

Mayer, M. The schools. New York: Harper & Row, 1961.

Mayer, W. V. Biological sciences curriculum study. In Course and curriculum improvement projects. (NSF Rep. No. 0-389-256) Washington, D.C.: United States Government Printing Office, 1970.

Montgomery, J. L. A comparison of BSCS versus traditional teaching methods by testing student achievement and retention of biology concepts. Columbia, Ohio: ERIC, Information Analysis Center, 1970.

Montrose, G. M. (Ed.) A program for teaching science. Part I Thirty-first yearbook of the national society for the study of education. Chicago: University of Chicago Press, 1932.

Neidt, C. O. Use of videotaped instructional television for teaching study skills in a university setting. AV Communication Review, 1967, 15, 269-284.

Osbourn, E. S., Brown, A. S., & Van Hooft, G. E. Organization and administration for curriculum development in science. In N. B. Henry (Ed.), Rethinking science education. Part I. The fifty-ninth yearbook of the national society for the study of education. Chicago: University of Chicago Press, 1960.

Palmer, E. L. How elementary school children resolve experimentally produced conflicts in thinking (U.S. Office of Education Cooperative Project No. 3216). In I. J. Athey & D. O. Rubadeau (Eds.), Educational implications of Piaget's theory. Waltham, Mass.: Ginn-Blaisdell, 1970.

Palmer, E. L. Factors related to persistence in inquiry. Alberta Journal of Educational Research, 1967, 13, 15-25.

Palmer, E. L. The equilibration process: some implications for instructional research and practice. In I. J. Athey & D. O. Rubadeau (Eds.), Educational implications of Piaget's theory. Waltham, Mass.: Ginn-Blaisdell, 1970.

Piaget, J. The psychology of intelligence. London: Routledge & Kegan Paul, Ltd., 1950.

Piaget, J. Development and learning. Journal of Research in Science Teaching, 1964, 2, 176-186.

Piaget, J. Science of education and the psychology of the child. New York: Orion, 1970.

Pinard, A., & Laurendeau, M. A scale of mental development based on the theory of Piaget: description of a project. Journal of Research in Science Teaching, 1964, 2, 253-260.

Popham, W. J. Instructional idea tapes in teacher education. AV Communications Review, 1966, 14, 371-377.

Price-Williams, D. R. A study concerning concepts of conservation of quantities among primitive children. In I. J. Athey & D. O. Rubadeau (Eds.), Educational implications of Piaget's theory. Waltham, Mass.: Ginn-Blaisdell, 1970.

Rainey, R. G. A comparison of the CHEM study curriculum and a conventional approach in teaching high school chemistry. School Science and Mathematics, 1964, 64, 539-541.

Raubinger, F. M., Rowe, H. G., Piper, D. L., & West, C. K. The development of secondary education. Toronto: Collier-Macmillan, 1969.

Raun, C. E. The interaction between curriculum variables and selected classroom student characteristics. Dissertation Abstracts, 28:01A:1629, November, 1967.

Raven, R. J. The development of the concept of momentum in primary school children. Journal of Research in Science Teaching, 1967, 5, 216-223.

Reynolds, G. S. A primer of operant conditioning. Chicago: Scott Foresman, 1968.

Schirner, S. W. A comparison of student outcomes in various earth science courses taught by seventeen Iowa teachers. Unpublished doctoral dissertation, University of Iowa, 1967.

Schulman, L. S., & Keislar, E. R. Learning by discovery, a critical appraisal. Chicago: Rand McNally, 1966.

Schurdak, J. J. An approach to the use of computers in the instructional process and an evaluation. American Educational Research Journal, 1967, 4, 59-73.

Schwab, J. J., & Brandwein, P. F. The teaching of science. Cambridge: Harvard University Press, 1962.

Shamos, M. H. Science and common sense. In E. Victor & M. F. Lerner (Eds.), Readings in science education for the elementary school. New York: Macmillan, 1967.

Shuford, E. H., Albert, A., & Massengill, H. E. Admissible probability measurement procedures. Psychometrika, 1966, 31, 125-145.

Sigel, I. E., & Hooper, F. H. Logical thinking in children. New York: Holt, Rinehart, and Winston, 1968.

Skinner, B. F. Science and human behavior. New York: Macmillan, 1957.

Skinner, B. F. The technology of teaching. New York: Meredith Corp., 1968.

Smart, M. What Piaget suggests to classroom teachers. Childhood education, 1968, 44, 194-300.

Smedsland, J. The acquisition of conservation of substance and weight in children: I. Introduction. Scandinavian Journal of Psychology, 1961, 2, 11-20.

Smock, C. D. Children's conception of reality: some implications for education. Journal of Research and Development in Education, 1968, 1, 30-37.

Spiess, M. L., Thiel, R., & Leventhal, E. Performance as a function of feedback condition. In V. Crockenberg (Ed.), American educational research association, paper abstracts. Washington, D.C.: American Educational Research Association, 1969.

Stafford, D. The influence of the science curriculum improvement study, first-grade program on the attainment of the conservations. Dissertation Abstracts, 30:7:2862-A, January, 1970.

Suchman, J. R. The Illinois studies in inquiry training. Journal of Research in Science Teaching, 1964, 2, 230-232.

Travers, R. M. W. Essentials of Learning. New York: Macmillan, 1967.

Troxel, V. A. Analysis of instructional outcomes of students involved with three courses in high school chemistry. Dissertation Abstracts, 29:6:1832-A, December, 1968.

Tuddenham, R. D. Psychometricizing Piaget's methode clinique. In I. J. Athey & D. O. Rubadeau (Eds.), Educational implications of Piaget's theory. Waltham, Mass.: Ginn-Blaisdell, 1970.

Underhill, O. E. The origins and development of elementary school science. Chicago: Scott Foresman, 1941.

APPENDIXES

APPENDIX A: The Testing Instruments

Metropolitan Science Test, Advanced Battery

The Metropolitan Science Test, Advanced Battery was used to measure science ability. The test contains fifty-five items of the information generalizations, and understandings most commonly covered in science programs in grades 7, 8, and 9.

The following percentage distribution of the content is believed to be representative of the curriculum offerings for which the test is designed.

Area	Percent
Life Science (environment and growth of plants and animals; balance in nature)	18
Earth Science (composition and history of the earth; astronomy; weather)	19
Physical Science (sound; light; air; water; magnetism and electricity; machines; atomics; chemical change)	36
Conservation (animal; soil; water; plant)	6
Health (nutrition and growth; body systems and processes; safety)	21

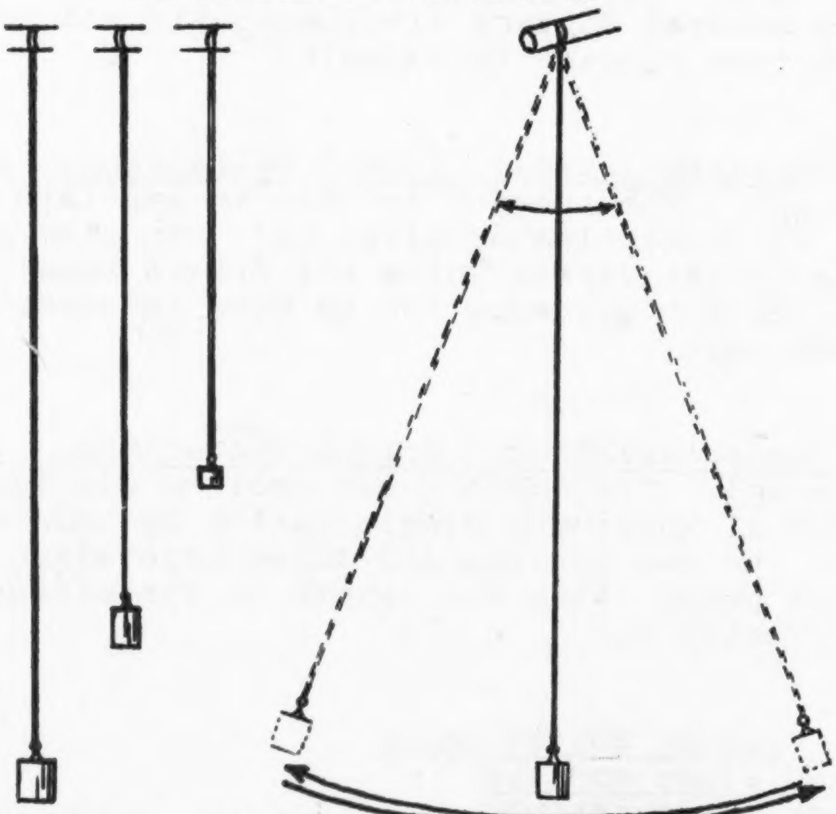
The reliability of the test has been determined by the split-half method. The coefficient for Form BM is .85. The Spearman-Brown Prophecy Formula has been used in correcting the split-half coefficient.

DESCRIPTION OF TASKS

Task 1. Oscillation of a Pendulum and the Operations of Exclusion

Figure 5

EXPERIMENTAL APPARATUS



The apparatus consists of four weights of varying size, four lengths of string, and a ring stand with a rod attached to enable the weight to swing freely from the string (Inhelder & Piaget, 1958, p. 68).

Problem. The problem is to find which of the four variables determines the frequency of oscillation of the weight.

Instructions and Procedure. The subject is instructed to tie a string on each weight and then tie the string to the rod. When this is done, the subject is further instructed to drop the weight from any height and then push the weight to get it into oscillation. This procedure is to be followed for all four weights. The subject is told to decide if the speed of oscillation is the same for all weights or is the speed different, and to state the reason for the decision.

Characteristics: Concrete Operations. Stage II-A (Disequilibrium). The serial ordering of weights is not accurate and variables cannot be isolated. The subject will attribute causal roles to the weight and the dropping point, because he varies several conditions simultaneously.

Characteristics: Concrete Operations. Stage II-B. (Equilibrium). The Stage II-B subject can accurately order weights, cannot isolate variables one-by-one. This subject will vary several factors simultaneously and indicate that each factor in turn implies the result.

Characteristics: Formal Operations. Stage III-A (Disequilibrium). The subject is able to separate the variables, and when the investigator gives aid, can make combinations in which one factor varies while the others remain constant. The student does not yet know how to make the combinations in any consistent way.

Characteristics: Formal Operations. Stage III-B (Equilibrium). The subject can isolate all variables present by the method of varying a single factor by holding all others constant. He can exclude all three irrevelant factors and determine, with proof, that the length of the string is the only relevant variable.

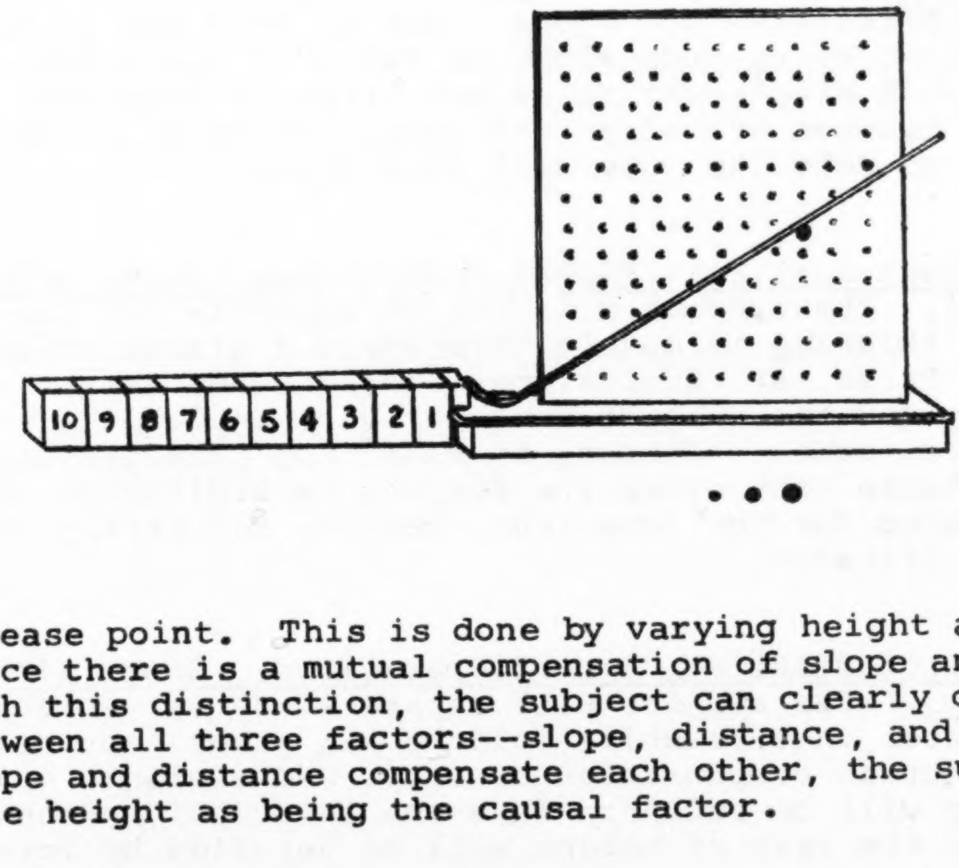
Task 2. Falling Bodies on an Inclined Plane and the Disjunction Operations

The inclined plane can be adjusted for various angles of incline. Four marbles of varying weight and size are rolled down the plane one at a time. The marble hits a springboard at the base of the inclined plane, then will bound in a parabolic curve and come to rest in one of the compartments (numbered 1 to 10). This is the index to the length of bound (Inhelder & Piaget, 1958, p. 81).

Problem. The problem is to find the relationship between the height of the point from which the ball is released and the length of the bound. Since the length of the bound varies only as a function of the height of the release point the subject will arrive at a successful answer when a distinction by disjunction is made between slope, distance, and height of

Figure 6

EXPERIMENTAL APPARATUS



release point. This is done by varying height and distance since there is a mutual compensation of slope and distance. With this distinction, the subject can clearly distinguish between all three factors--slope, distance, and height. Since slope and distance compensate each other, the subject can isolate height as being the causal factor.

Instructions and procedure. The subject is told to place the plane at any height, and to change the height as he wishes. He is given four marbles and asked to roll them, one at a time, down the slope. He is to guess, before the release of each marble, which compartment it will fall in and tell why he made the guess. (This is to allow for exclusion of the factors of size and weight of the marbles. The investigator asks if size or weight have an effect.)

If the subject's behavior indicates that the plane cannot be changed the investigator intercedes and makes this change, and asks for an explanation of the results.

Characteristics: Concrete Operations. Stage II-A (Disequilibrium). The weight of the marble can be isolated insofar as it is incompatible with any serial correspondence. There is an exact serial ordering of the slopes and lengths of the bounds with approximate correspondence between the two. Elevation and the possibility of separation of the distance traveled from the slope of the plane are not considered.

Characteristics: Concrete Operations. Stage II-B (Equilibrium). The subject begins to dissociate the height of the release point from the slope. But he does not go far enough in his thinking to exclude slope in favor of the height. He deals only with single variables and tries to formulate a correspondence between the slope and length of bound so that the marble will go into the same slot each time.

Characteristics: Formal Operations. Stage III-A (Disequilibrium). The subject will try to separate out the variables. The thinking is unable to produce a dissociation of the variables. First, at equal slopes distance and height vary concurrently and the subject does not distinguish the two factors from each other. Second, in asserting that distance and slope compensate each other the subject is limited to covariance without looking for the invariant, height, and partly confuses height with distance.

Characteristics: Formal Operations. Stage III-B (Equilibrium). The subject will separate out variables by varying each factor in turn while holding all other factors constant. There is a mutual compensation of slope and distance and this relationship will be varied. Thus the invarient, height, is isolated and the role of height will be verified by formulating a law upon request.

Task 3. Combinations of Colored and Colorless Chemical Bodies

Five similar flasks containing colorless and odorless liquids are numbered from one to four with the fifth container marked "g." The solutions are: (1) diluted sulphuric acid, (2) water, (3) oxygenated water, (4) thiosulphate, and (5) potassium iodide. Each container has a dropper in it. Several clean flasks are provided for use in mixing the solutions (Inhelder & Piaget, 1958, p. 107).

Problem. To combine the solutions directly in order to establish a combinational system in relation to propositional logic.

Instructions and procedures. The investigator presents to the subject two beakers, one containing 1 + 3, the other containing 2. In front of the subject, he pours several drops of "g" into each flask and notes the differences. The subject is then asked to reproduce the yellow color, using flasks 1, 2, 3, 4, and "g" as he wishes, and explain how he did it.

Characteristics: Concrete Operations. Stage II-A (Disequilibrium). One-by-one correspondence is the only logical multiplication operation which occurs to the subject. The combinations of liquids will be 1 + 2 + 3 + 4 + "g" or one solution with "g." Two-by-two combinations will not occur. Color will be sought only in particular solutions, not combinations.

Characteristics: Concrete Operations. Stage II-B (Equilibrium). This subject will demonstrate a two-by-two combination or a three-by-three combination. The combinations are not systematic and all possible combinations are not attained. Color will be sought in particular elements rather than combinations.

Characteristics: Formal Operations. Stage III-A (Disequilibrium). An establishment of a systematic n-by-n combinational system occurs. When 1 X 3 X "g" is combined and yellow occurs the subject sets about to make other combinations.

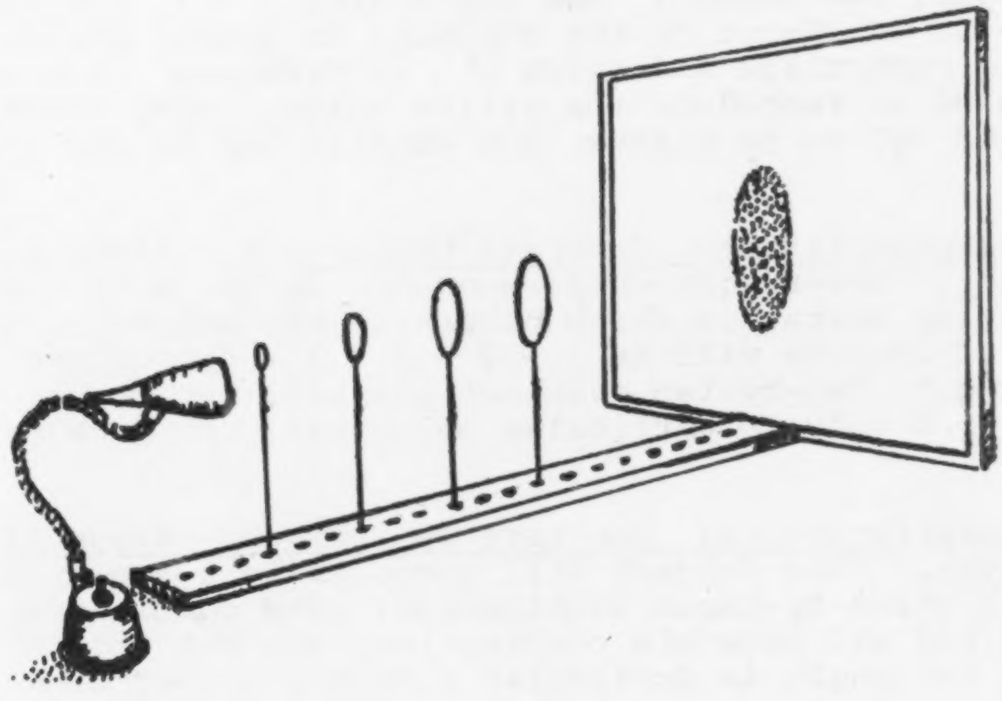
Characteristics: Formal Operations. Stage III-B (Equilibrium). This subject will present the proof of the color by deductive conclusion. The 1 X 3 X "g" combination will be made and 2 and 4 will be added alternately to determine the effect.

Task 4. Projection of Shadows

The apparatus consists of a baseboard, a white screen attached to one end of this, a lamp for a light source, and four rings of varying diameters. The light source and the rings can be moved along the baseboard (Inhelder & Piaget, 1958, p. 200).

Figure 7

EXPERIMENTAL APPARATUS



Problem. Two shadows of the same size are to be projected on the screen, using two different sized rings.

Instructions and procedures. The investigator presents the Experimental Apparatus, turns on the light, and asks the subject to make two shadows of equal size by using two rings of different size and explain how he did it.

Characteristics: Concrete Operations. Stage II-A (Disequilibrium). The subject can serially order the size of the rings and the size of the shadows. He is able to formulate accurate correspondences at equal distances. The serial ordering of distances is not related to the size of the shadows.

Characteristics: Concrete Operations. Stage II-B (Equilibrium). The subject will establish a correspondence between the decreasing sizes of the shadows thrown by the same ring and the increasing distances from the light source. They understand that the closer the object is to the screen, the smaller the shadow. Distance will be calculated by starting from the screen, rather than the light source.

Characteristics: Formal Operations. Stage III-A (Disequilibrium). The subject begins to calculate distances from the light source rather than the screen. Consideration is given to the distance between the light source and the first ring, not just simply the distances between the rings. The subject will reach the verification of his hypothesis with a single case because he has not yet conceived of the relationships as changeable. He does not look for the general law, defined as a system of necessary relations which are adequate to account for the proof of the result.

Characteristics: Formal Operations. Stage III-B (Equilibrium). The subject will proceed to the generalized statement and proof of the law. This is defined as: a given increase in the diameters of the rings combined with a given increase in distance can give the same results as other combinations of increases or decreases.

APPENDIX B: The Teacher's Manual

TITLES OF MICROUNITS

The materials consist of seventeen related microunits. Concepts for each microunit are listed for the teacher, with behavioral objectives. The students are provided with behavioral objectives for each microunit. Skill units are provided when necessary. The general titles are listed below with suggested time allotment.

Microunit	Title	Number of Investigations (One day per investigation as to time. Exceptions noted.)
Skills I	Microscope Technique	4 investigations
1	Cell Structure	3 investigations
2	Structure of Cells, Tissues, and Organs	1 investigation
3	Plant Structure; Cells, Tissues, Organs	6 investigations
4	Life Processes; Plants and Animals	8 investigations
5	Use of Oxygen and Carbon Dioxide by Plants and Animals	4 investigations
6	Plant and Animal Adaption to the Environment	5 investigations
7	Dissection	4 investigations
8	Behavior	4 investigations
9	Human Physiology	21 investigations

Microunit	Title	Number of Investigations (One day per investigation as to time. Exceptions noted.)
10	Classification Skills	1 investigation
10	Classification	6 investigations
11	Classification	2 investigations
12	Classification	2 investigations
13	Factors Influencing Establishment of Land Ecosystems	2 investigations * investigation 2 requires 6 weeks to complete
14	Water Ecosystems	2 investigations
15	Soil Chemistry: PH value	3 investigations
16	Plot to Study Ecology	8 investigations * investigation 5 requires 1 week to complete * investigation 6 requires 3 weeks to complete
17	Soil Organisms and Plot Change	5 investigations

*Plan to work on microunits simultaneously when necessary.

CONCEPTS DEVELOPED IN THE MICROUNITS

Microunit 1: Cell Structure

1. Each part of the cell has a function in the maintaining of life.
2. Cells are made up of specialized parts.

Microunit 2: Structure of Cells, Tissues, and Organs

1. Similar tissues form organs, which perform some special function in keeping the plant or animal alive.
2. Cells which are alike form tissues.
3. The basic building blocks of plants and animals are cells.

Microunit 3: Plant Structure; Cells, Tissues and Organs

1. A plant is made up of cells, tissues, and organs.
2. A leaf is an organ of the plant.
3. Leaves are specialized to perform photosynthesis, respiration, and transpiration.

Microunit 4: Life Processes

1. Plants and animals carry on all life processes.
2. Plants require carbon dioxide, chlorophyll, water, and sunlight to carry on photosynthesis.
3. Plants and animals are dependent upon each other for life.

Microunit 5: Use of Oxygen and Carbon Dioxide

1. Plants and animals are interrelated in use of the atmosphere.
2. Plants use carbon dioxide and release oxygen.
3. Animals use oxygen and release carbon dioxide.

Microunit 6: Plant and Animal Adaptations to the Environment

1. Organisms are adapted to their environment.
2. Food and oxygen must be present in the environment for animals to survive.
3. Plants and animals cooperate and help each other to live.

Microunit 7: Dissection

1. Animals have internal systems which are adapted to living in the environment.
2. Systems are made up of organs, which perform a certain life function for the organism.

Microunit 8: Behavior

1. Animals behave in a manner for protection and propogation of the species.
2. Behavior is controlled by the nervous system in animals.
3. Human behavior is the action resulting from stimuli.

Microunit 9: Human Physiology

1. The human body is a complex combination of systems to carry on life processes.
2. Chemical breakdown of food is accomplished by natural body fluids.
3. Food is chemically broken down to simple nutrients for cell use.
4. Every cell carries on all life processes.

Microunit 10: Classification

1. Classification varies because relationships can be interpreted in different ways.

Microunit 11: Classification

1. Classification has two aims; convenience and expressions of relationships.
2. The two aims of classification often conflict.

Microunit 12: Classification

1. Some microorganisms live together and this relationship makes for classification conflict.
2. Organisms are classified by external and internal features.

Microunit 13: Factors Influencing Establishment of Land Ecosystems

1. Light and temperature affect the growth of plants.
2. Establishment of a species in an ecosystem depends upon the species tolerance and competition.
3. The naturally occurring organisms in any given area are those that can survive and successfully reproduce under environmental conditions prevailing there.

Microunit 14: Water Ecosystems

1. The chemistry of fresh water differs from sea water.

2. The concentration of dissolved substances in water environments influence the types of living organisms found in the environment.

3. The type of populations in fresh water ecosystems affect the successional changes which occur.

Microunit 15: Soil Chemistry: pH Value

1. Soil has chemical characteristics.
2. The pH of the soil indicates if it is acid or base.
3. A pH of 7 indicates that the substance is neutral.
4. A pH of any number below 7 indicates acid.
5. A pH of any number above 7 (until 14 is reached) indicates base.
6. Any coloring substance changes chemically when there is an increase or decrease in the pH of the water where they are dissolved. This chemical change is indicated by a change in color.

Microunit 16: Plot to Study Ecology

1. The amount of sunlight available affects the type of plant growing in the area.
2. Change occurs in nature.
3. One type of leaf behavior is that they turn by the petiole with angle of the direction of sunlight.

Microunit 17: Soil Organisms and Plot Change

1. Plants and animals are dependent upon each other.
2. Soil contains living organisms.
3. The organisms help to maintain the chemical balance of available minerals in the soil for plants to use.
4. Some of the soil organisms cause decay of organic matter.
5. Animals depend upon plants for food.

GLOSSARY

Behavior. An observable response to a stimulus emitted by an organism.

Cognitive Structure. Various modes of knowing, perceiving, remembering, imagining, conceiving, judging, and reasoning. The cognitive structure is an aspect of conscious life and is contrasted with the affective or feeling function of consciousness.

Concrete Operations. The ability to structure thought on the basis of additive or multiple classifications. These elementary groupings of thought are systems of simple or multiple class inclusion or linkage. They do not include a combinational system linking the various given elements n-by-n. The mechanism of reversibility used by the subject consists of inversion or reciprocity, and the two are not integrated into a single system.

Conjunction. Propositions are combined by the conjunction "and," e.g., p and q.

Correspondence. Relations are obtained among objects serialized according to two sorts of relations at once, e.g., "one to one correspondence" or one term can be made to correspond to several others as father to his sons.

Curriculum Materials. A systematic organization of instructional materials designed to provide students with classroom learning activities of concrete operations and formal operations with secondary reinforcement.

Deductive Reasoning. Process of drawing a conclusion on the basis of accepted judgments or known facts to determine relationships.

Disjunction. In logic, combination of propositions by "not both p and q," p and q being propositions.

Equilibrium. The condition of thought where a system of balancing interactions and alterations with the structure of operational wholes being conserved while new elements are being added. Equilibrium is existent when operations, which the subject is capable of, constitute a structure such that these operations can be performed in either one of two directions, by strict inversion, reciprocity or negation. The total set of possible operations constitute a system of operations which compensate each other as far as they conform to reversibility.

Equilibrium in Concrete Operations. The transformations are superordinate to static situations and every experience is conceived of as a result of the transformation. Transformations have acquired reversibility and the potential to coordinate according to fixed laws of composition. Transformations are assimilated to operations, which result from internalization of actions and regulations. Equilibrium is mobile at this stage. The organization of the concrete groupings easily attains stability, but instability appears with coordination of the groupings, as the thinking can handle only a limited set of potential transformations.

Equilibrium in Formal Operations. The thinking allows reality to become secondary to possibility. The thinking involves considering the given facts as a section of a set of possible transformations that have actually occurred. These facts are neither explained or regarded as facts until the subject undertakes verifying procedures that pertain to the entire set of hypotheses compatible with a given situation. When verbal statements are substituted for objects thinking includes propositional logic. It constitutes a combinational system of thinking. Equilibrium extends to the extent that potential transformations compensate each other. Structural possibility is equivalent to the potential available.

Formal Operations. The organization of thought so that the groupings of concrete operations are associated and integrated into a single combinational system. The n-by-n generalized classification becomes a set of all possible classifications compatible with the given base associations. The subject can see the "structured whole" of the n-by-n combinations.

The mechanism of reversibility is such that the subject's thinking includes negation and reciprocity so integrated that reality is a function of possibility. Formal operations constitute the structure of the final equilibrium.

Groupings. An organization of propositions which satisfies the law of a commutative group. Logical grouping is defined by the operations of composition, inversion, identity, and associativity. Thus: $A + A' = B$; $B + B' = C$ (Composition); $A - A' = B$; hence $A = B - A'$ and $A' = B - A$ (Inversion); $A - A = 0$ (Identity); $A + (A' + B') = (A + A') + B'$ but $A + (A - A) \neq (A + A) - A$ (Associativity); $A + A = A$; hence $A + B = B$ (Tautology).

Implication. Propositions are combined as e.g., if p, then q.

Operations. The thinking process involved in transforming data about the real world so that it is organized and used selectively to solve problems. Operations are reversible and internalized in the mental process.

Reversibility: Negation. The ability to isolate a variable in respect to its being present in experimental results in some cases and absent in others.

Reversibility: Reciprocity. The type of ability to eliminate a variable for the purpose of analyzing its role or to analyze variations on the other associated variables.

Student's Ability to Move Into Formal Operations. The instability of concrete operations, mobile equilibrium, will be a variable acting to induce the thinking to formal operations. Concrete operations thought does not solve all of the problems raised by the interference of heterogeneous operations or intersections of different properties. There exists a progressive adaptation process, in the area of adaptations indispensible to action, in the form of the potential future. When an internalized action becomes an operation; possibility intervenes at every case when the subject, after having imagined where each of several actions leads, must make a choice. Thus the successions of mental activities is not only affected by the operations actually performed but also by the entire set of possible operations insofar as they orient the mental searching toward deductive closure. To make use of this mobile equilibrium in the classroom the concrete operations student will encounter experiences in the curriculum materials which involve heterogeneous operations, intersecting of groupings, and extending the potential into the realm of possibility.

Problems concerning the roles of social interaction during the semester will be encountered because the students will be working together and sharing learning experiences. These social problems and structures arise as being acute to the adolescent. The more adept a subject becomes in social interaction which is distinct from coercion and involves cooperation the more the behavior expresses the constitution and development of logic. Actual exchanges of thought obey a law of equilibrium. The interaction of thought between individuals consists of systems of groupings where action involves a series of complimentary actions of reciprocity and consistency. Equilibrium is established between individual thought and social activity, as one depends upon the other (Piaget, 1950).

Thus, it is hypothesized by this investigator that the concrete operations subject will recognize gaps in his thinking. These gaps resulting from experiences within the curriculum materials and social interaction of the classroom environment. The mobile equilibrium present will be a factor that is changing and the subject will be induced to establish the equilibrium of formal operations.

THEORETICAL BACKGROUND AND OBJECTIVES

There are several objectives to consider in the implementation of this project. First and upmost, is the consideration of the student. The student is conceived as being an individual learner with a cognitive structure that is in a developmental process. Piaget considers the intelligence of the individual as a developmental sequence that progresses with increasing chronological age and experience to the formal operations. Thus, the student is not thought to as an adult in respect to the intellectual function.

The seventh grade student exhibits the behavior classified as concrete operations. The student conceives of reality as being foremost in the thinking process. An elementary form of equilibrium has been reached and the equilibrium is in a mobile condition. Groupings can be structured. The groupings present are logical in nature, i.e., those which start with individual elements (classes and relations) which are regarded as constant and simply consists of the serialization of them. Reversibility is present for the first time. Yet the student is unable to connect the groupings into a structured whole of all n-by-n combinations.

The development of formal operations is dependent upon the concrete operations. This level appears with reality becoming secondary to possibility. The student engages in thinking from a sector of all possible transformations compatible with the given situation. The thinking precedes from what is possible to what is empirically real. The structured whole is thought of as the total of all n-by-n combinations.

For further clarification of the two levels of development, a listing of some expected behaviors is given for concrete operations and formal operations. These behaviors can be used by the teacher as a guide in evaluating the behavior emitted by the students.

Concrete operations behavior as described by Inhelder and Piaget

1. Serial ordering and one-to-one correspondence without seeking to know the reasons behind the transaction.

2. A factor can be isolated from the correspondence and the thought can precede from one link to another without relating each partial link to all of the others.

3. Does not isolate factors from the context and use deductive reasoning to determine relationships.

4. Views the problem in terms of all possible combinations in such a way as to draw out implications or nonimplications instead of noting empirical links in order and draw tables of correspondences.

5. Capable of differential classification, formation of hierarchies of more or less of inclusive classes. Individuals are considered from a basis of being equivalent, e.g.,

(A + A') - B = A + (A' + B') = C, etc., serial ordering or equalizations, and correspondences which are all accurate when considered independently but, when taken together they prove nothing. Unable to verify action of one factor by having all other known factors constant, the subject does not realize verification used in the thinking is worthless.

6. Cannot isolate variables because of viewing several conditions simultaneously. Lacks a formal combinational system because of lack of conceiving multiplicity of combinations.

7. Cannot exclude relationships, but does conceive two independent factors which compensate each other. Lacks ability to exclude the particular relationships necessary to reach a solution.

8. Can systematically structure groupings and classes and perform operational disjunction. Can isolate a variable which is ineffective, but cannot perform the correspondence between factors to reach a solution.

9. Is concerned with reality with little thought given to possibility. Cannot see the entire whole as being all possible n-by-n combinations.

Formal operations as described by Inhelder and Piaget (1958).

1. Can perform a necessary combination of possibility, hypotheses, and deductive reasoning with consideration of all

possible combinations.

2. Considers the variation effect of a single factor with all others being equal. Can prove that a given factor does play a causal role. Has the ability to take all possible combinations and isolate a single factor and variations of effect and determine entire relationships between variables. Separates variables according to combinations not given by direct observation. Relationships are determined by operations of conjunction and implication.

3. Can bring the result of several groupings of classes and relations into a single whole.

4. Able to isolate all variables present by the method of varying a single factor while holding all others constant. Able to exclude all unnecessary variables to reach a solution.

5. Deductively finds product of compensation, isolates variables and demonstrates proof.

6. Can operate with disjunction, conjunction, negation, implication and form the sixteen binary combinations of propositional logic.

7. Possibility no longer becomes an extension of actions actually performed (as in concrete operations) but reality becomes secondary to possibility, the set of given facts as a sector of possible transformations compatible with the given situation. The thinking precedes from what is possible to what is empirically real.

Behavioral objectives are written in terms for the teacher to use as well as being stated for the student. Direction in the learning process is provided through the student behavioral objectives. The student should be aware of what is expected of him as to behavior changes. Since the student knows the expected behavior changes he can have opportunity for self-evaluation, develop self-confidence, and self-direction in the learning process. The concrete operations student will exhibit behaviors different from the formal operations student. Yet, each response can be accurate.

Science is regarded as a body of knowledge accompanied by understandings that must be added to the cognitive structure of the student. With science knowledge and understanding the student can better comprehend and enjoy the world he lives in.

In order for understanding to take place the educational environment must be conductive to learning. It is believed that curriculum materials designed to provide guided discovery experience will actively engage the student in learning. As the concrete operations student works through the investigations the characteristic of dealing with reality can be utilized. Also, opportunity for the formal operations level of thinking is provided. The student is given freedom to make answers suitable to his particular level of thinking.

Reinforcement is provided by means of the answer sheets which are given to the teacher. The student will have free access to this media of reinforcement. He has opportunity to correct mistakes without undue stress. For the objectives is to provide a means by which the student has ample opportunity to realize gaps in his thinking and utilize the mobile equilibrium present in the cognitive structure of the concrete operations. It is by the addition of new information and restructuring of this information that the student develops the level of thinking termed formal operations. New information is made available to the concrete operations student by the answer sheets because both the concrete operations and formal operations answers are available, each level of answer being the correct response.

Social interaction is allowed by the design of the curriculum materials. Piaget believes that social interaction, free from coercion, allows freedom for the student to develop a logical behavior which is the evidence for logical thought. The students are encouraged to work in groups, discuss the investigations and have discussion groups with and without the teacher. The student can learn to live with the results of his actions and establish a pattern of success and failure which is logical in nature.

Since opportunities are provided for individual learning by a guided discovery method, the role of the teacher becomes different from the lecture method of teaching. In fact the role of the teacher in the guided discovery method is very important. The teacher assumes the role of a resource person. This means the teacher is aware at all times of what the students are working with, problems they encounter, and is ready to give requested assistance. The assistance given the students should be by means of a questioning technique to guide the student's thinking. Answers should not be told but asked so the student can deduct the answer. The teacher will be active in discussion groups and be free to assist wherever needed. It is hoped that the teacher can become very aware of the learning behaviors of the concrete operations and the formal operations. This awareness will enable the teacher to utilize the mobile equilibrium, present in the concrete operations, in the questioning technique.

The objective of this study is to find out if experience in concrete operations and formal operations with secondary reinforcement can facilitate the concrete operations students to develop the formal operations level of thinking. It is impossible to give the students all of the information they will ever need to live in the ever-changing world. If we, as teachers, can given opportunity to develop thinking abilities which enable the student to have the ability and self-confidence to solve problems we have become successful in developing the student in the cognitive as well as the affective realm of his conscious life.

APPENDIX C: The Sample Microunit

MICROUNIT (11) II CLASSIFICATION

FOR TEACHERS ONLY

Concepts

1. Classification has two aims: convenience and expression of relationships.

2. The two aims of classification often conflict.

Investigation 1: Materials include a group of twenty insects; two pair of different species of true beetles, two pair of different species of true bugs, two grasshoppers, two moths, three butterflies, two ants (one red, one black), two flies, one dragonfly.

Investigation 3: Materials include a group of twelve specimen of common wild flowers in bloom from the area. Two evening primroses (one white, one pink), two dandelions, one gallardia, one bitterweed, two daisies, two day flowers, one bluebonnet, one Indian paint brush. They may be obtained in mass and transplanted for use. Other specimen can be substituted.

Investigation 5: Materials include five specimen; one grass plant, one frog, any composite wild flower, one earthworm, one cricket.

Behavioral Objectives

The classification of each group will be written by the students based upon information listed as observed characteristics. See answer sheets for possible answers.

MICROUNIT 11

CLASSIFICATION

Concepts

1. Classification has two aims, convenience and expression of relationships.

2. The two aims of classification often conflict.

Behavioral Objectives

1. Given several plant and animal specimen, the student will arrange them on the basis of observation, into a classification system.

2. The groups and subgroups will be generated on the basis of likenesses and differences of external structure.

3. Justification of the arrangement will be demonstrated by listing the external characteristics for the groups and subgroups that were generated from observation.

Investigation 1

Materials. Twenty preserved specimen numbered from 1-20. (Teacher information: includes within the group of twenty insects, two pair of different species of true bugs, two pair of different species of true bettles, two grasshoppers, two moths, three butterflies, two ants (one red and one black), two flies, 1 dragonfly). Magnifying glass.

Arrange the twenty specimen into a classification system. Use the number of each specimen instead of names. Make as many groups and subgroups as you can justify from your observation.

Tell how and why you classified the twenty specimen as you did. ______________________________

____

____

Investigation 2

Observe the same twenty specimen and write answers to the following questions:

List the ways in which all of the twenty specimen are alike. ______________________________

____

____

How do the twenty specimen differ from each other?

____

____

Write a classification system for the twenty specimen on the basis of the likenesses and differences you have observed and recorded in Investigation 2. ______________________________

____

____

Tell why and how you made this classification system.

Is the classification system of Investigation 1 like the system of Investigation 2?

If the systems are different, which do you think is the better one for your class to use to classify?

Why?

If the systems are alike, tell why you think they are practical for classification purpose.

Can other specimen be put into your classification system?

If so, how?

Investigation 3

Materials. Twelve fresh specimen numbered from 1-12. (Teacher information: these specimen should consist of twelve wild flowers in bloom from the area: two evening primroses (one white and one pink), two dandelions, one gallardia, one bitterweed, two daisies, two day flowers, one bluebonnet, one Indian paint brush. They may be obtained in mass and transplanted for growing in the classroom.)

Arrange the twelve specimen into a classification system. Use the number of each specimen instead of names. Make as many groups and subgroups as you can justify from your observation.

Tell how and why you classified the twelve specimen as you did. ______________________________

____

____

Investigation 4

Observe the twelve specimen and write the answers to the following questions. (You may make charts if you wish.)

List the ways in which all of the twelve specimen are alike. ______________________________

____

____

List the ways in which the twelve specimen are different. ____

____

____

From the likenesses and differences you have listed, make a classification system using the twelve specimen. Write the reason you used for making each group and subgroup. ____

____

____

Is the classification system in Investigation 3 like the system of Investigation 4? ____________________

____

____

If they are different, which one is better for the class to use to classify? ______________________

____

____

Why? ____

____

____

If the two systems are like, tell why you think they are useful for classification purposes. ______________

____

____

Can other specimen be put into your system? If so, how?

Investigation 5

Using the information you have gathered and generated from Investigation 1 through 4, make one big classification system using all thirty-two specimen. You may do this anyway you wish. The only requirement is that the reasons for your classification system should be written to prove your work.

Investigation 6

Materials. Five specimen numbered from 33-38. (Teacher information: these specimen are a grass plant, a frog, any composite wild flower, an earthworm, and a cricket.)

Examine the five specimen. Put them into the classification system you have arranged in Investigation 5.

Tell why you put them into the system where you did.

Decide how you can do this and insert the new specimen into the system by number.

You may have decided that a discussion session is necessary by this time. If you wish you may form a group and talk about what you have done and compare your classification systems. Invite your teacher to join the dicussion.

APPENDIX D: The Judging Procedures

DIRECTIONS TO THE JUDGES

You are to judge the underlined student questions, the student answers, and the Clarification, Justification, and Rationale. The judge will attempt to determine if the question following the laboratory investigation is open enough to allow an individual student to answer the question at either the concrete or formal operations stage of development.

To facilitate the judging, student answers that reflect both the concrete and formal operations stages are included. This will allow the judges to verify that the investigator can distinguish between the concrete and formal answer and that the questions do allow for both types of student answers.

The rationale for the investigator's decisions are also included. The judges should also judge the rationale as to the appropriate description of the thinking involved for the concrete and the formal answers.

The procedure for judging is listed below:

1. Read the microunit.

2. Read the question that is to be judged (indicated by the judging marking box).

3. Read the student answers (indicated by Concrete Answer and Formal Answer).

4. Read the rationale.

5. Judge the question asked in the investigation and place a check mark under Yes or No. The criterion to consider

is: Is the question open enough to allow for a concrete answer and a formal answer at the same time. (This means that a concrete operations answer will be a successful answer as well as a formal operations answer, depending upon the ability level of the student.) Thus, the question will allow the student to answer according to the ability to manipulate variables.

6. Judge the student answers as concrete or formal. Check the appropriate space in the boxes (Concrete, C; Formal, F).

7. Judge the rationale as to the accuracy in the description of the thought processes involved in solving the problem; include both the concrete operations and formal operations in the judging. Mark the appropriate space in the boxes.

Note: The judge is encouraged to add any comments pertinent to the decisions. Your time and effort is appreciated. Mark the boxes including your judgment of both concrete and formal operations, for example:

Yes		No	
C	F	C	F
✓	✓		

MICROUNIT (10) I CLASSIFICATION

FOR TEACHERS ONLY

Concept

Classification varies because relationships can be interpreted in different ways.

Behavioral Objectives

1. After observation under the microscope, the student will write sentences stating that:

    a. Green algae is classified as a plant because of the presence of chlorophyll and the cell wall.

2. After observation under the microscope the student will write sentences stating that:

    a. A paramecium, euglena, and amoeba have characteristics belonging to both the plant and animal kingdoms because of internal structure.

    b. The difference between the specimen is that the green algae is made up of cells linked together, while the amoeba, paramecium, and euglena are each single cells.

3. The student will collect data for one week about microorganisms grown in cultures. Interpretation of the data will be determined by written statements justifying the

classification on the basis of many variables of color, size, shape, food for growth, rather than structure alone.

STUDENT BEHAVIORAL OBJECTIVES

Investigation 1

After microscopic observation the student will indicate in writing:

1. The classification of algae as to kingdom and state the proof.
2. The differences between algae, paramecium, and euglena.
3. The classification of paramecium, euglena, and amoeba after observing and listing the characteristics.

Investigation 2

The student will write an interpretation of the data collected from observation of growth of the microorganisms, by classifying the organisms and stating the proof.

Investigation 1

Materials. Four cultures of live specimen, paramecium, euglena, amoeba, green algae, clean slides, microscope, two needles, and an eyedropper.

Procedure. Prepare a slide so that you can clearly see each of the four specimen under the microscope. From your microscopic observation, write the following information. You may make drawings also.

Describe the parts of the paramecium; outer boundary.

Describe parts inside the boundary.

Describe the parts of the euglena; outer boundary.

Describe parts inside the boundary.

Describe the parts of the amoeba; outer boundary.

Describe parts inside the boundary.

Describe the parts of the green algae; outer boundary.

Describe the parts inside the boundary.

Using the detailed description of the four specimen, write the following information.

List the ways these four specimen are alike.

List the ways these four specimen are different.

How would you classify these four specimen?

State your reasons for the classification.

Does the question have an opportunity for a concrete and a formal operations stage?

Yes		No	
C	F	C	F

ANSWER C: Algae and euglena are together because they have chloroplasts. Amoeba and paramecium don't have chloroplasts.

ANSWER F: The paramecium, euglena, and amoeba are grouped together because they are one celled. The green algae is different because the cells are connected.

Does the concrete answer fit the concrete operations criteria?

Does the formal answer fit the formal operations criteria?

Yes		No	
C	F	C	F

Verbal Interaction with Teacher

The concrete operations student explained his answer to the teacher in the following manner:

1. He stated that he saw chloroplasts in both the algae and euglena and he did not see chloroplasts in the amoeba and paramecium.

2. When asked by the teacher to state characteristics of a plant cell he replied that a plant cell has chloroplasts, cell wall, and cell membrane.

3. When the teacher asked the student to state the characteristics of an animal cell. The concrete student said that the animal cell has no chloroplasts, a cell membrane without a cell wall.

4. The teacher asked the student to explain his answer and he replied that he used only the presence or absence of chloroplasts to make the decision for his placing algae and euglena together (both have chloroplasts) and amoeba and paramecium together (both lack chloroplasts). He further explained that the cell wall did not make any difference in the classification because the presence or absence of chloroplasts was what made the difference between the specimen.

The formal operations student justified his classification to the teacher in the following manner:

1. When compared, the algae, euglena, paramecium, and amoeba have these likenesses and differences:

a. The formal student made the following chart for comparison of likenesses and differences.

PRESENCE OF:

cell wall	cell membrane	chloroplasts
algae	algae	algae
	euglena	euglena
	paramecium	
	amoeba	

b. In explaining the chart, the student stated that with just this contradictory information the four specimen cannot be classified because the algae has all three characteristics present.

2. So the formal student said that they can be classified on the basis of structure which does not contain the contraditions. He then proceeded to prove the classification by

microscopic observation. Algae has a multicellular structure because the cells are connected and this is one group. The amoeba, paramecium, and euglena are one celled in structure and this is the other group in the classification.

STRUCTURE
Many cells connected
algae

Single cells
paramecium
euglena
amoeba

Justification, Clarification, and Rationale

ANSWER C: The subject ignores the presence of a cell wall in the algae and formulates an answer just on the basis of one variable (chloroplasts).

ANSWER F: All contradictions are removed and the classification in on the basis of one celled versus multicelled structure.

Investigation 1 involves the elimination of contradictions (Inhelder & Piaget, 1958). In a previous microcunit the students has learned that the presence of a cell wall, cell membrane, and chloroplasts are characteristics of a plant cell. An animal cell is characterized by the presence of a cell membrane and the absence of both a cell wall and chloroplasts. In this investigation contradictions arise, as the paramecium, euglena, and amoeba have a cell membrane and chloroplasts, with an absence of a cell wall. So this is information which contradicts the knowledge possessed by the student, as one plant characteristic (chloroplasts) and one animal characteristic (cell membrane without cell wall) are found within one cell.

The concrete operations student becomes involved in the number of contradictions because he is not aware of the inconsistency of his answer since it does not include all of the available information. The solutions presented by this student lack final success or completion because of the inability to see the internal consistency of the structured whole. A coherent system of classification (removal of contradictions) is not yet formulated in the thinking process. The student vacillated between the two concepts (characteristics of plant cells and characteristics of animal cells) and was unaware that with the elimination of contradictions, a third concept (classification based only upon structure) can be formulated from the total amount of information. The solution presented by the concrete operations student ignored the presence of cell membrane, with or without cell wall, in the four specimen which is an actual contradiction in the classification system presented in the answer. Thus, the concrete operations student is unable to perform hypothetico-deductive thought that is required to arrive at the successful solution.

The formal operations student presented proof of the classification system by taking into account the total number of possible combinations. Procedures used to present the proof of the classification included the separation of variables according to all possible combinations, elimination of contradictions and the establishment of relationships on the basis of conjunction and implication. The formal operations student presented the successful answer because of the ability to formulate another existent relationship between the specimen after the contradictions were eliminated.

Appropriateness of Rationale

Does the rationale agree with Piaget's description of concrete and formal operations characteristics?

Yes		No	
C	F	C	F

Write the reasons for your classification as you did it. Can you think of another way to group the four specimen? If so, write your classification system and tell how you did it.

Does the question have an opportunity for a concrete and a formal operations stage?

Yes		No	
C	F	C	F

ANSWER C: Yes, the paramecium, euglena, and amoeba are in the same group because they have no cell wall. The algae is different because it has a cell wall.

ANSWER F: No, because I have used all of the available information. Does the concrete answer fit the concrete operations criteria. Does the formal answer fit the formal operations answer?

Yes		No	
C	F	C	F

Verbal Interaction with Teacher

The concrete operations student explained his answer to the teacher in the following manner:

1. He stated that there is another way to classify the specimen because he saw, under the microscope, that the algae had a thick cell wall. This was different because the thinner cell membrane was observed only in the amoeba, euglena, and paramecium.

2. Another way to classify the specimen was to put the amoeba, paramecium, and euglena in one group because of the cell membrane and no cell wall. The algae was in another group because of the cell wall (a thicker wall because it had the cell wall plus the cell membrane).

The formal operations student justified his "no" answer by stating that he had looked at all possible combinations on the basis of cell wall, cell membrane, and chloroplasts:

cell wall	cell membrane	chloroplasts
algae	algae	algae
	amoeba	euglena
	paramecium	
	euglena	

This grouping (cell wall and chloroplasts) presented contradictions to placement into one grouping so he looked for another feature for classification on the basis of what he knew. He decided that structure was the way to make the classification, because no contradictions were present:

Structure

Many cells connected
algae

Single cells
paramecium
amoeba
euglena

So in presenting proof of this answer, he had looked at all possible combinations and no other answer was available from his information.

Justification, Clarification, and Rationale

ANSWER C: Contradictions are ignored, and the subject chooses another single variable to justify the classification.

ANSWER F: There is only one successful answer after contradictions are removed by the subject.

Investigation 1 involves the elimination of contradictions. In a previous microunit the student has learned that the presence of a cell wall, cell membrane, and chloroplasts are characteristics of a plant cell. An animal cell is characterized by the presence of a cell membrane and the absence of both a cell wall and chloroplasts. In this investigation contradictions arise, as the paramecium, euglena, and amoeba have a cell membrane and chloroplasts, with an absence of a cell wall. So this is information which contradicts the knowledge possessed by the student, as one plant characteristic (chloroplasts) and one animal characteristic (cell membrane) are found within one cell.

The concrete operations student becomes involved in the number of contradictions, he has ignored the presence of chloroplasts in the algae and euglena. The solutions presented by this student lack final success because of the inability to see the internal consistency of the structured whole. A coherent system of classification (removal of contradictions) is not yet formulated in the thinking process. The student vacillated between the two concepts (characteristics of plant cells and characteristics of animal cells) and was unaware that with the elimination of contradictions, a third concept (classification based only upon structure) can be formulated from the total amount of information. The solution presented by the concrete operations student ignored the presence of chloroplasts in the four specimen which is an actual contradiction in the classification system presented in the answer. Thus, the concrete operations student is unable to perform hypothetico-deductive thought that is required to arrive at the successful solution.

The formal operations student presented proof of the classification system by taking into account the total number of possible combinations. Procedures used to present the proof of the classification included the separation of variables according to all possible combinations, elimination of contradictions and the establishment of relationships on the basis of conjunction and implication. The formal operations student presented the successful answer because of the ability to formulate another existent relationship between the specimen after the contradictions were eliminated.

Appropriateness of Rationale

Does the rationale agree with Piaget's description of concrete and formal operations characteristics?

Yes		No	
C	F	C	F

Investigation 2

You will need to plan ahead to set up the materials, grow the cultures and record data each day for at least a week for this investigation. You may work in groups of 2 or 3. Organize the entire class so that each group has a symbol as Group A, Group B, Group C, etc.

Materials. Glass marking crayon, ten small clear plastic containers, very ripe fruit (a plum, an apple, an orange, a lemon). Five to ten very ripe grapes, water from pond or lake containing materials from the bottom and top surface scum, hay or dried grass, dried beans, cottage cheese or cream cheese, lettuce, bread, filter paper, garden soil, cornstarch, spatula, clear covers for plastic containers, microscope, hand lens or magnifying glass, forceps, two needles, medicine dropper, slides, two pieces of stale bread, a scale and weights in grams, cover slips, a liquid measuring container marked in milliliters.

Procedure. Set up the cultures in the following manner. (Follow this procedure so that every group will have the same pattern.) Mark the plastic containers with your group symbol and number them 1-10. (For example, GA1, GA2, GA3, GA4, etc.) Place the materials in the containers as follows:

Container 1.	Fruit, cut into pieces.
Container 2.	Grapes, slightly crushed with enough water to cover them.
Container 3.	Water from pond containing surface and bottom materials.
Container 4.	Hay or dried grass, enough to cover the bottom and 200 ml of water.
Container 5.	A few dried beans, covered with 200 ml of water.
Container 6.	Cottage cheese or cream cheese spread over bottom of container.
Container 7.	Lettuce leaves, broken into small pieces in a little water.
Container 8.	Two pieces of stale bread, moistened with water. (Caution: Do not soak the bread.) Expose this container to the air 24 hours before covering.

Container 9. Place a piece of filter paper on the bottom of the container. Mix 5g of cornstarch with 95g of soil. While mixing add just enough water to give the mixture a doughlike consistency. Spread the mixture on the filter paper, using the spatula to make a smooth surface. Keep this mixture moist with water during the time of the entire investigation.

If any of the containers fit tightly, place the end of a flat toothpick between each container. (Be sure to leave container eight open for twenty-four hours as directed.)

Data is to be collected by observation of the nine containers each day.

Make a chart in the space provided. Include in the chart the date of the observation, number of the container, descriptions of how culture looked with just your eyes and then with testing them and anything else you can find.

Organize your chart information in a manner pleasing to you. After the cultures have grown some, look at each one under the microscope. You can record this data in chart form, also. Drawings may help you to record changes your observe.

From all of the information you have, how would you classify the cultures?

Justify your classification by telling why and how you did the classification.

Does the question have an opportunity for a concrete and a formal operations stage?

Yes		No	
C	F	C	F

ANSWER C: Group 1 - Containers 1 and 2 because they are green.

Group 2 - Containers 3 and 4 because they have little microscopic organisms that are not colored.

Group 3 - Container 6 because it is the only yellow one.

Group 4 - Containers 7 and 8 because they are black.

Group 5 - Containers 5 and 9 because nothing happened.

ANSWER F: Group 1 - Containers 1 and 2 because the culture grew on fruit which tested to be acid.

Group 2 - Containers 3 and 4 because microscopic organisms are present.

Group 3 - Container 8 because the culture grows on bread which tested to be carbohydrate.

Group 4 - Container 6 because the culture grows on cheese which tested to be protein.

Group 5 - Container 7 because the culture is on lettuce which contains cellulose.

Group 6 - Containers 5 and 9 because nothing happened.

Does the concrete answer fit the concrete operations answer?

Does the formal answer fit the formal operations answer?

Yes		No	
C	F	C	F

Verbal Interaction with Teacher

The concrete operations student explained his answer to the teacher in the following manner:

1. Some of the containers changed color after they sat for a week.

2. Color was the most obvious change that occurred so that was the classification basis for the answer.

The formal operations student explained his answer to the teacher in the following manner.

1. The containers changed after they sat for a week, because the cultures grew on the substances we put into the containers.

2. Even though the colors were different this was not enough information to classify the cultures.

3. Decided to test the growth media to find if they were different.

The student demonstrated to the teacher the testing procedure results of each test justifying his answer. (This type of testing had been experienced by the students in microunit 9 and the testing agents were available in the classroom.)

The student was able to combine a relationship between culture growth and the growth media and could justify his answer on this basis of relationship existing between them.

Clarification, Justification, and Rationale

This investigation has been proceeded by Microunit 9 which involved the students in obtaining information about foods. Testing of various foods was done to detect the presence of protein, starch, sugar, acid, base, and fats. The chemistry of the growth media is a factor which will influence conjunction relationships in the structuring of the classification system required in this investigation. These conjunctions can express a relationship of reciprocal exclusion in some cases and in some cases can be substituted, one for the other without influencing the result. Thus, information has been made available so that the student will be able to consider more than just the observable characteristics of color, size, and growth patterns of the cultures.

This investigation involves the separation of variables (Inhelder & Piaget, 1958). The concrete operations system of thinking involved the construction of serially ordered tables of association or correspondences either of classes or relationships. The student was unable to verify the action of one factor by leaving all other known factors constant. The thinking did not include the generalization ability and the system of thinking lacked the realization that the verification by testing and providing his results. The parts of the whole (culture and growth media) are integrated by implication which is broader than the simple correspondence of concrete operations. The possibilities are integrated simultaneously by disjunction and because of this, a single structured whole is developed from groupings of classes and relations.

Appropriateness of Rationale

Does the rationale agree with Piaget's description of concrete and formal operations characteristics?

Yes		No	
C	F	C	F

APPENDIX E: Intellectual Performance in Formal Operations

Table 6

Intellectual Performance in Formal Operations (Stage III)

Subject	Experimental		Control	
	Pretest	Posttest	Pretest	Posttest
1	1	4	1	1
2	3	3	1	2
3	1	2	1	1
4	1	2	1	3
5	3	4	1	3
6	3	4	3	2
7	1	4	2	1
8	0	4	1	2
9	2	4	2	3
10	0	4	1	2
11	1	4	0	1
12	1	4	0	1
13	1	4	1	2
14	2	4	1	1
15	2	4	0	1
16	1	4	2	2
17	2	4	2	3
18	2	4	3	3
19	1	4	0	2
20	0	4	1	2
21	2	4	3	2
22	1	4	2	4
23	0	4	1	3
24	2	4	2	1
25	1	4	1	3
26	1	4	1	2
27	0	3	1	3
28	1	4	1	1
29	1	3	1	1
30	1	3	1	2
31	1	4	0	3
32	1	4	1	2
33	1	4	0	3
34	3	4	1	3
35	0	1	1	1
36	1	3	1	2
Mean	1.25	3.64	1.17	2.06

Note: Each score is the total responses for each subject recorded in formal operations for all four of the tasks.